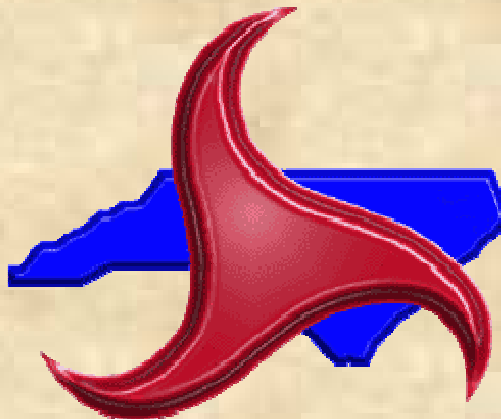


Trip Generation Training



Prepared by NCDOT

Traffic Engineering & Safety System Branch

Access Management Group

What is Trip Generation?

- ✓ Institute for Transportation Engineers (ITE)
 - Research to find a correlation between variables and trips generated by different land uses.
- ✓ Purpose of Calculations
- ✓ Background of Trip Generation
 - Based off thousands of studies and utilizing statistical analysis for forecasting.

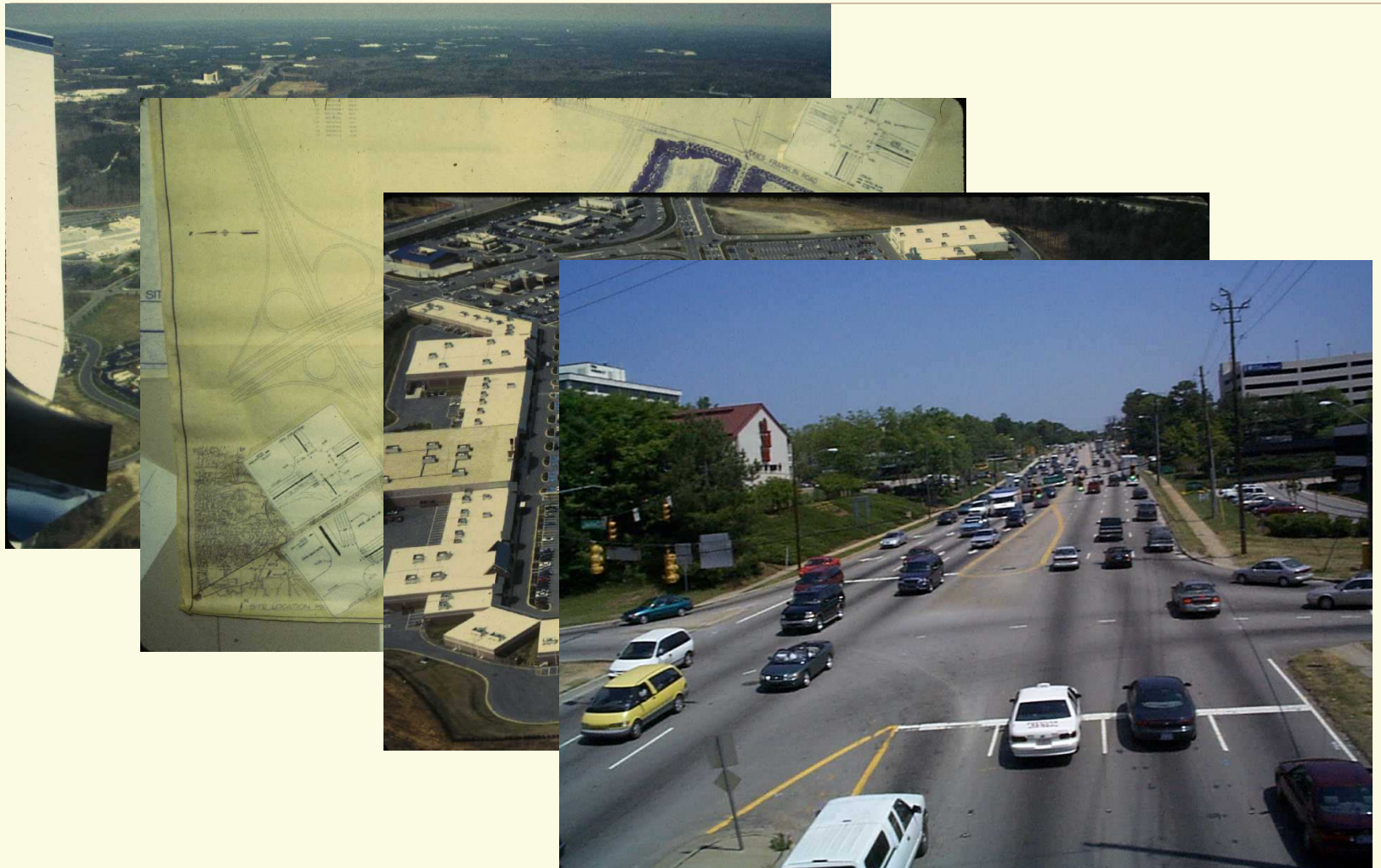
Objectives

- ✓ To provide an understanding of the aspects of Trip Generation.
- ✓ To understand the factors which effect the calculations of trips for a particular land use.
- ✓ To estimate future traffic volumes upon which transportation improvements are based.

Agenda

1. Definitions and Factors of Trip Generation
2. Rate or Equation? The 8 Step Process
3. Simple Example Worksheet
4. Pass-by Trips
5. Pass-by Trips Worksheet
6. Internal Capture
7. Final Example Worksheet
8. Software Training

Purpose in Pictures



Definitions

- ✓ Average Trip Rate
- ✓ Trip or Trip End
- ✓ AM and PM Peak Hour Volume of Adjacent Street Traffic
- ✓ Average Trip Rate for the Peak Hour of the Generator
- ✓ Average Weekday Vehicle Trip Ends
- ✓ Average Weekday Trip Rate
- ✓ Independent Variable
- ✓ Areas (GLA, GRA, GFA)
- ✓ Multi-use Developments
- ✓ Internal Capture Rate

Selecting Independent Variables

✓ Choose a variable that:

A. Most directly causes variation in trip ends.

B. More appropriately reflects the proposed development.

✓ Relates to land use type, not development type.

Example → Business Park

✓ Check for adequate sample size.

Example → Drive-in Bank

Independent Variables

✓ Examples:

- Fast Food Restaurant
 - GLA
 - Seats
- Discount Store
 - GFA
 - Employees
- Golf Course
 - Employees
 - Acres
 - Holes

Selecting Time Period

- ✓ The time period analyzed should be the time period in which the combination of the trip generated traffic and adjacent street traffic is the maximum (Normally weekdays).
- ✓ Emphasis should be placed on weekday peak hours.
- ✓ Areas of high tourism, college areas, and seasonal effects should be monitored with caution.

Complex Sites

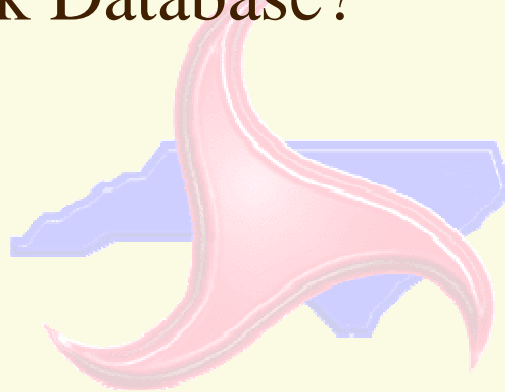


Methods for Trip Generation Estimations

1. Regression Equation
 2. Weighted Average Trip Generation Rate
 3. Data Plot (Local Data Collection)
- ✓ The objective is to choose the method which gives the most accurate estimation.

Analysis Selection

- ✓ Step 1. Is the land use in the Trip Generation Handbook Database?



Supermarket (850)

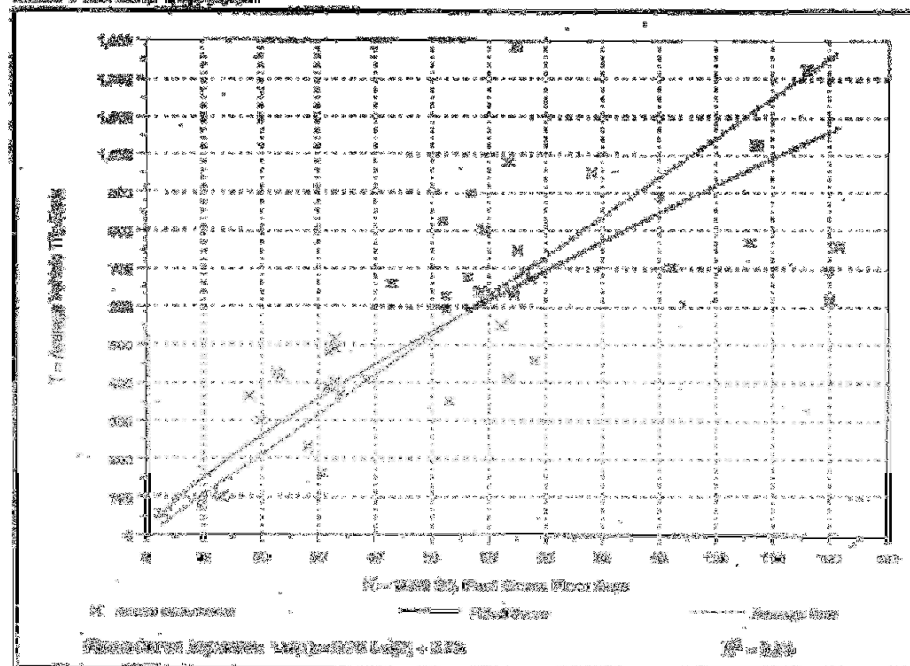
Average Vehicle Trip Ends on 1400 Sq. Feet Gross Floor Area
Building,
Peak Hour of Asphum Street Traffic,
One Hour Between 4 and 5 p.m.

Number of Studies 42
Average 1000 Sq. Feet 50
Structural Construction 81% existing, 19% existing

Trip Generation per 1000 Sq. Feet Gross Floor Area

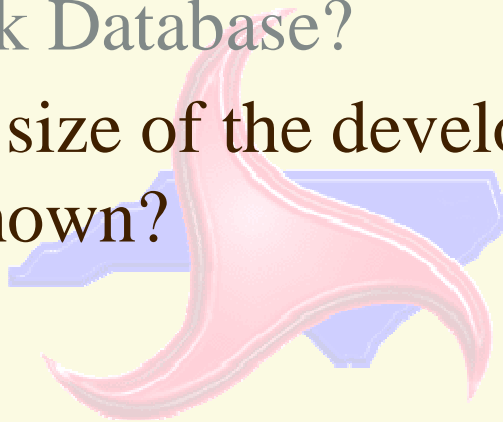
Average Value	Range of Values	Standard Deviation
12.72	8.11 - 22.15	4.27

Linear Plot and Regression



Analysis Selection

- ✓ Step 1. Is the land use in the Trip Generation Handbook Database?
- ✓ Step 2. Is the size of the development in the range of data shown?



Supermarket (850)

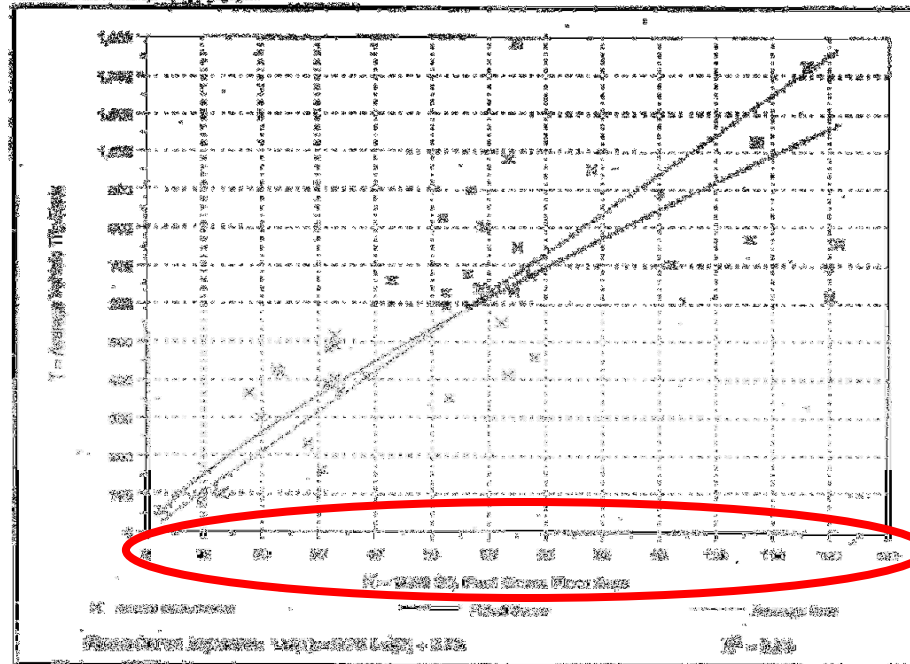
Average Vehicle Trip Ends on 1400 Sq. Feet Gross Floor Area
Building,
Peak Hour of Aspinwall Street Traffic,
One Hour Between 4 and 8 p.m.

Number of Studies 42
Average 1000 Sq. Feet 50
Structural Construction 81% existing, 19% existing

Trip Generation per 1000 Sq. Feet Gross Floor Area

Average Value	Range of Values	Standard Deviation
12.72	8.11 - 22.15	4.27

Linear Plot and Regression



Analysis Selection

- ✓ Step 1. Is the land use in the Trip Generation Handbook Database?
- ✓ Step 2. Is the size of the development in the range of data shown?
- ✓ Step 3. How many data points are in the sample?

Supermarket (850)

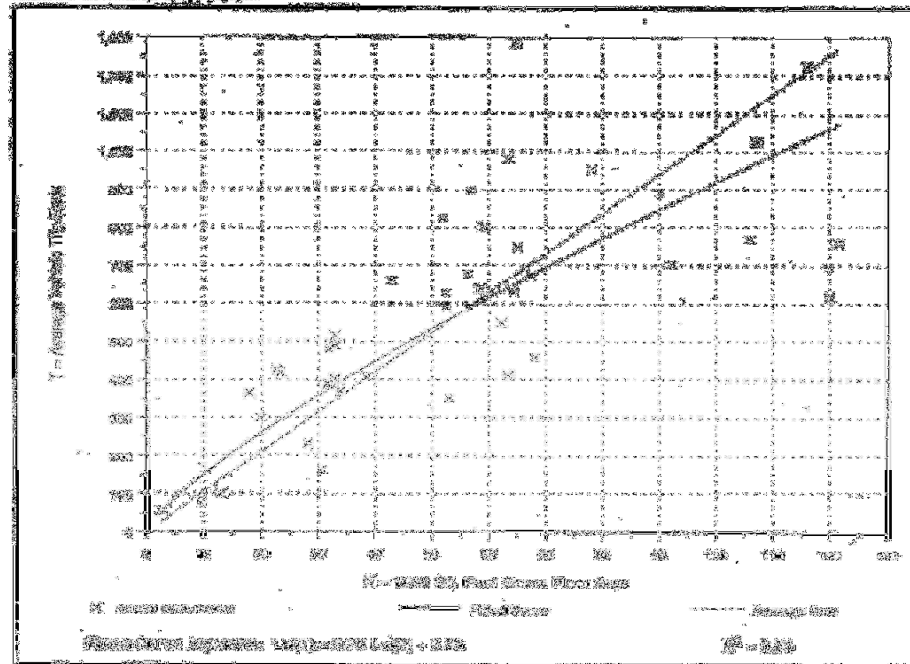
Average Vehicle Trip Ends on 1400 Sq. Feet Gross Floor Area
Building,
Peak Hour of Maximum Street Traffic,
One Hour Between 4 and 8 p.m.

Number of Studies 42
Average 1000 Sq. Feet 85
Educational Institutions 81% working, 19% not working

Trip Generation per 1000 Sq. Feet Gross Floor Area

Average Value	Range of Values	Standard Deviation
12.72	8.11 - 22.15	4.27

Linear Plot and Regression



Analysis Selection

- ✓ Step 1. Is the land use in the Trip Generation Handbook Database?
- ✓ Step 2. Is the size of the development in the range of data shown?
- ✓ Step 3. How many data points are in the sample?
- ✓ Step 4. Is a regression equation provided?

Analysis Selection

- ✓ Step 1. Is the land use in the Trip Generation Handbook Database?
- ✓ Step 2. Is the size of the development in the range of data shown?
- ✓ Step 3. How many data points are in the sample?
- ✓ Step 4. Is a regression equation provided?

Supermarket (850)

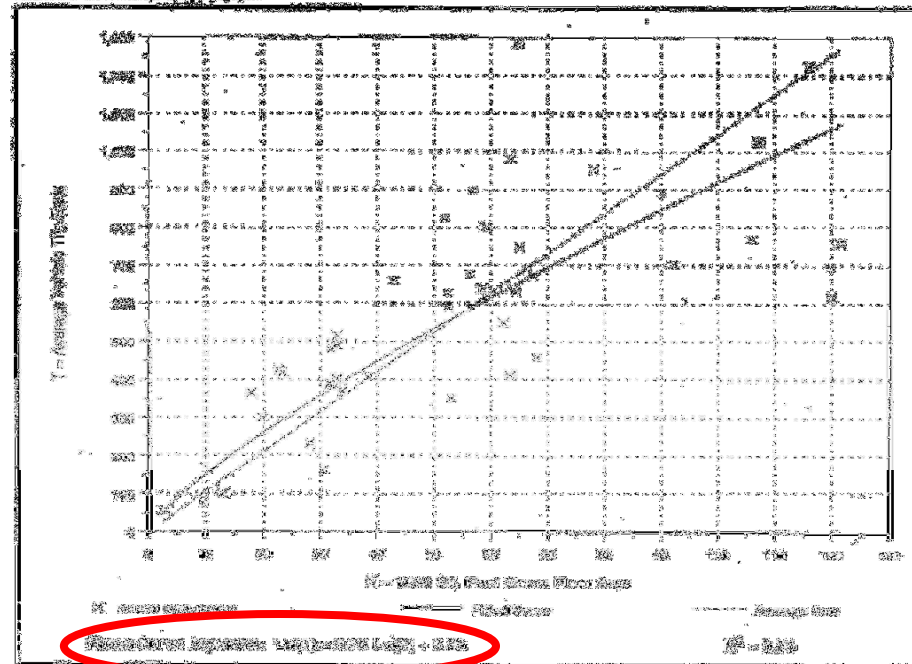
Average Vehicle Trip Ends on 1400 Sq. Feet Gross Floor Area
Building,
Peak Hour of Aspinwall Street Traffic,
One Hour Between 4 and 8 p.m.

Number of Studies 42
Average 1000 Sq. Feet 50
Structural Construction 87% existing, 13% existing

Trip Generation per 1000 Sq. Feet Gross Floor Area

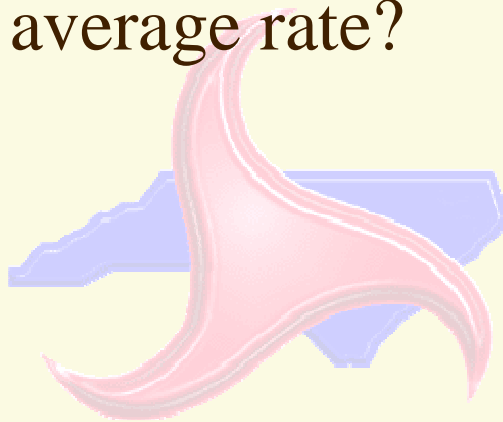
Average Value	Range of Values	Standard Deviation
42.72	21.71 - 65.15	14.27

Linear Plot and Regression



Analysis Selection (cont.)

- ✓ Step 5. Is the standard deviation ≤ 1.10 of the weighted average rate?



Supermarket (850)

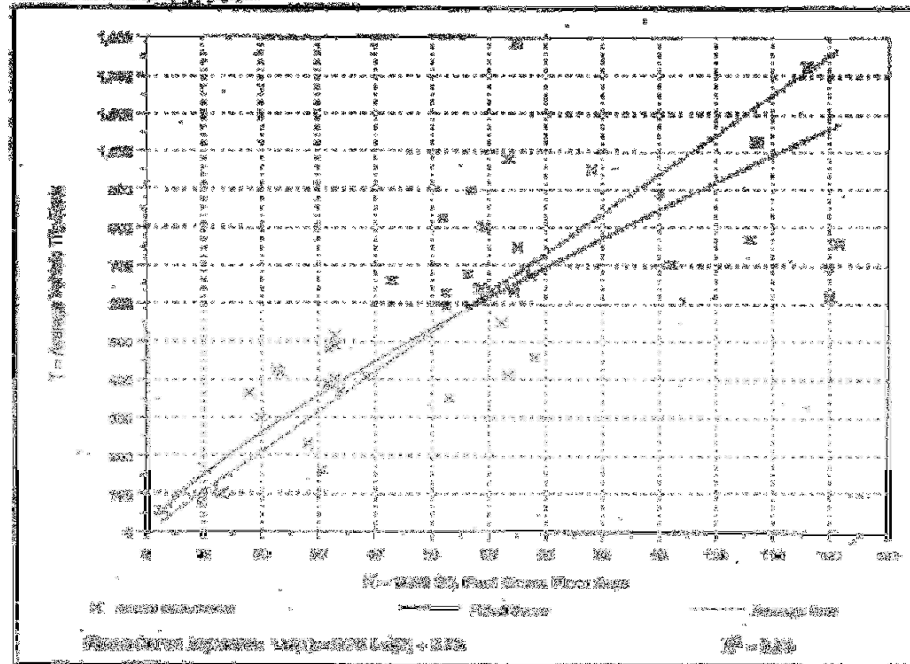
Average Vehicle Trip Ends on 1400 Sq. Feet Gross Floor Area
Building,
First Entry of Asphaltn Street Traffic,
One Hour Between 4 and 8 p.m.

Number of Studies 42
Average 1000 Sq. Feet 50
Structural Construction 51% existing, 49% existing

Trip Generation per 1000 Sq. Feet Gross Floor Area

Average Rate	Range of Rates	Standard Deviation
12.72	8.11 - 22.15	4.27

Linear Plot and Regression



Analysis Selection (cont.)

- ✓ Step 5. Is the standard deviation ≤ 1.10 of the weighted average rate?
- ✓ Step 6. In the graph, is the weighted average line within the cluster of data points at the value for the independent variable?

Supermarket (850)

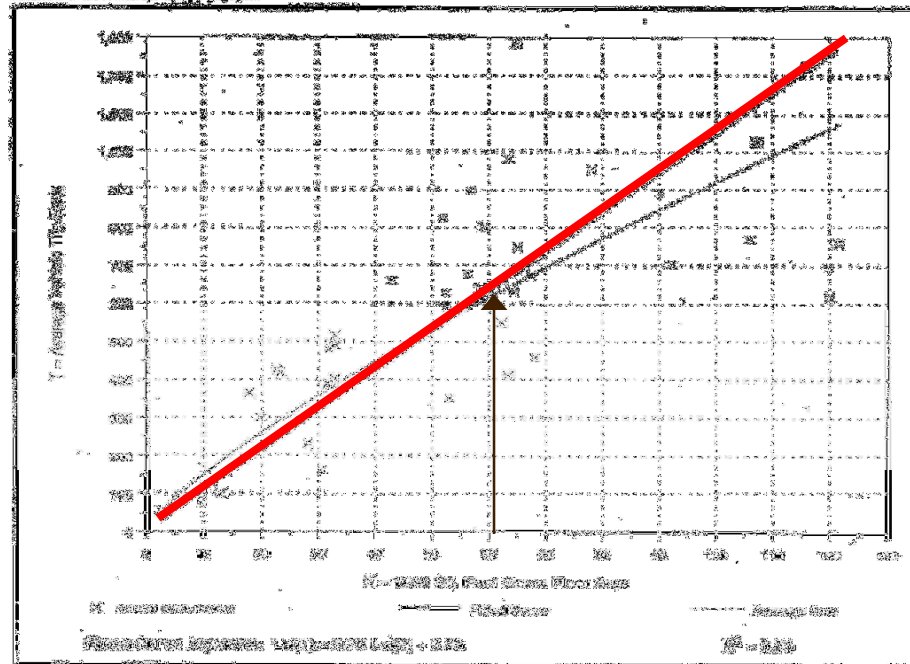
Average Vehicle Trip Ends on 1400 Sq. Feet Gross Floor Area
Building,
Peak Hour of Aspinwall Street Traffic,
One Hour Between 4 and 5 p.m.

Number of Studies 42
Average 1000 Sq. Feet 50
Structural Construction 81% existing, 19% existing

Trip Generation per 1000 Sq. Feet Gross Floor Area

Average Value	Range of Values	Standard Deviation
42.72	21.71 - 63.75	14.27

Linear Plot and Regression



Analysis Selection (cont.)

- ✓ Step 5. Is the standard deviation ≤ 1.10 of the weighted average rate?
- ✓ Step 6. In the graph, is the weighted average line within the cluster of data points at the value for the independent variable?
- ✓ Step 7. Are there at least 20 data points in the area of the independent variable?

Analysis Selection (cont.)

- ✓ Step 5. Is the standard deviation ≤ 1.10 of the weighted average rate?
- ✓ Step 6. In the graph, is the weighted average line within the cluster of data points at the value for the independent variable?
- ✓ Step 7. Are there at least 20 data points in the area of the independent variable?

Supermarket (850)

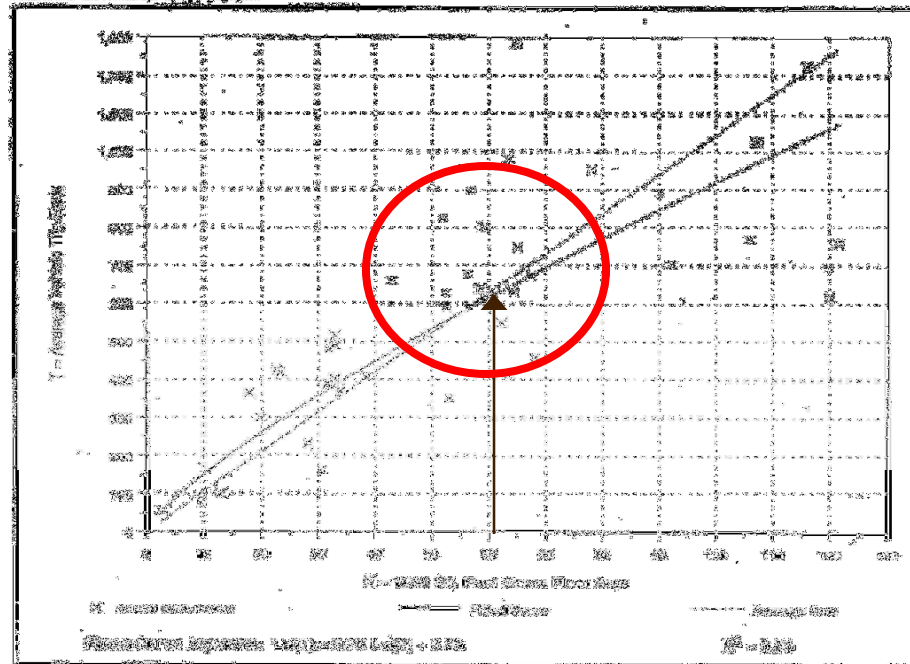
Average Vehicle Trip Ends on 1400 Sq. Feet Gross Floor Area
Building,
Peak Hour of Aspinwall Street Traffic,
One Hour Between 4 and 8 p.m.

Number of Studies 42
Average 1000 Sq. Feet 50
Structural Construction 81% existing, 19% existing

Trip Generation per 1000 Sq. Feet Gross Floor Area

Average Value	Range of Values	Standard Deviation
12.72	8.11 - 22.15	4.27

Area Plot and Regression



Analysis Selection (cont.)

✓ Step 8. Answer both 8A and 8B.

- 8A. Is the $R^2 \geq 0.75$? And, is the regression equation line within the cluster of data points?
- 8B. Is the standard deviation ≤ 1.10 of the weighted average rate? And, is the weighted average rate line within the cluster of data points?

Supermarket (850)

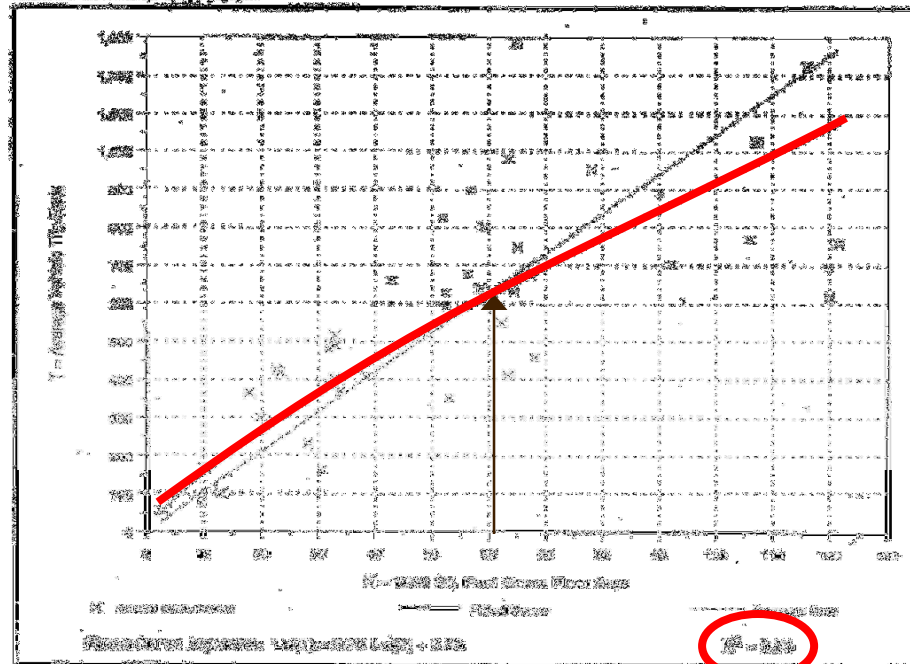
Average Vehicle Trip Ends on 1400 Sq. Feet Gross Floor Area
Building,
Peak Hour of Aspinwall Street Traffic,
One Hour Between 4 and 5 p.m.

Number of Studies 42
Average 1000 Sq. Feet 50
Structural Construction 81% existing, 19% existing

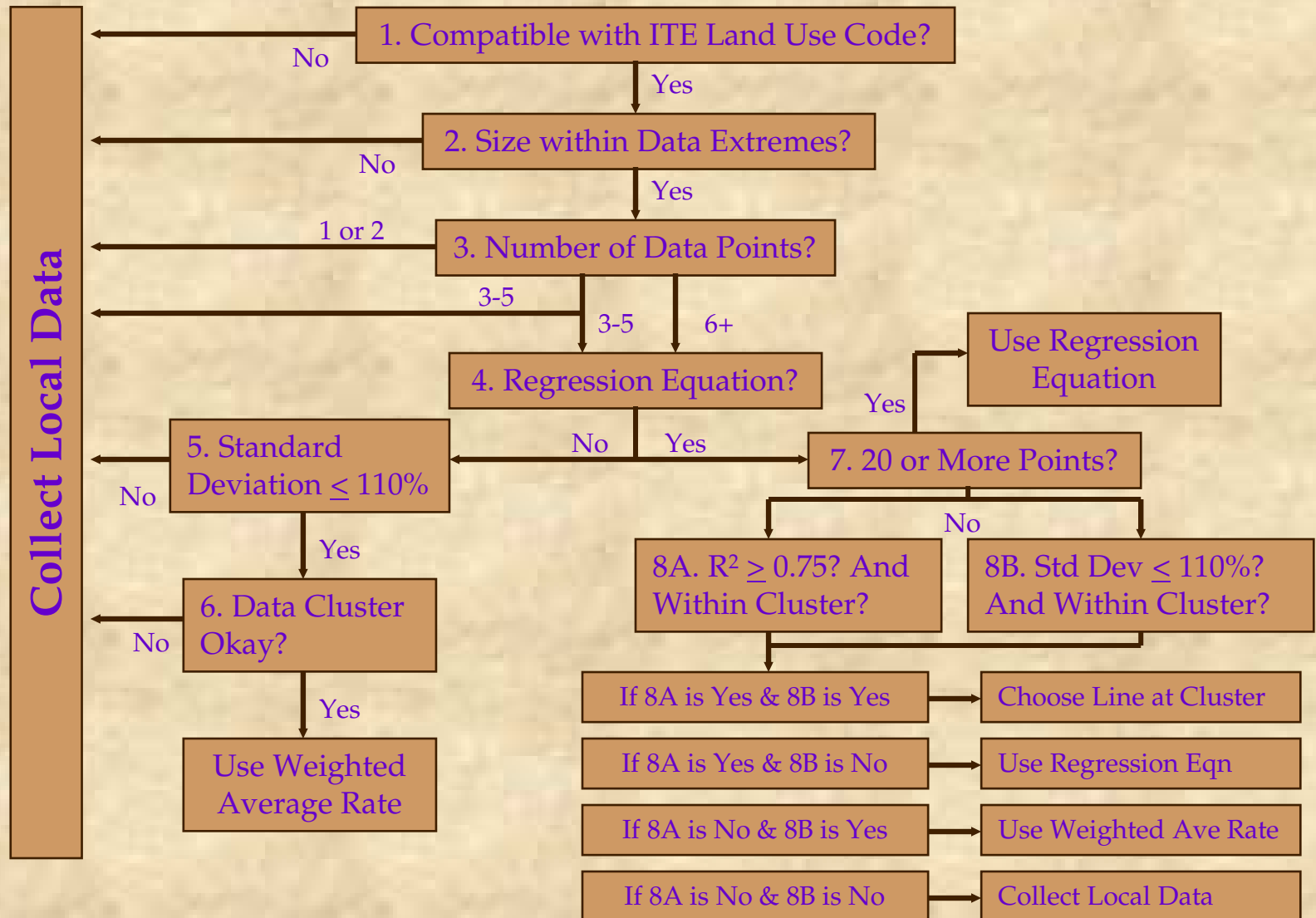
Trip Generation per 1000 Sq. Feet Gross Floor Area

Average Value	Range of Values	Standard Deviation
12.72	8.11 - 22.15	4.27

Linear Plot and Regression



Selecting Between Rates and Equations



Trip Generation Data Sheet

PM Trip Rate Example

Example #1 (Single Entrance)

Land Use: General Office Building (200,000 sf)

ITE Land Use Code: 710

Variable(s): Employees; 1,000 SF Gross Floor Area

Known Data:

45 mph

2-lane facility (11 foot lanes)

2 foot shoulders (paved)

ADT = 13,500

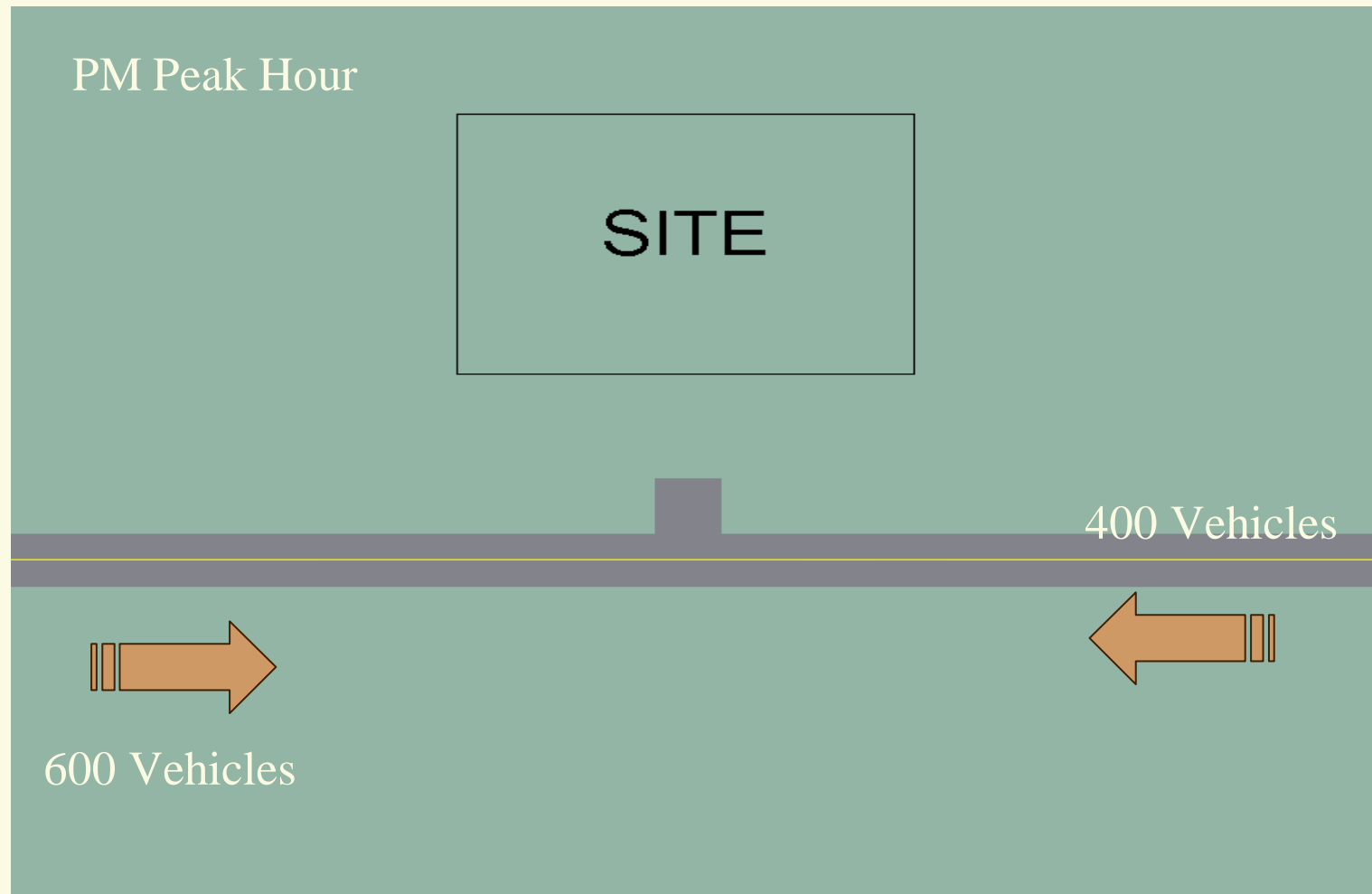
No trip reductions

Objectives

- ✓ Determine current peak volume on the facility (base/background traffic).
- ✓ Utilizing the ITE Trip Generation Manual, calculate the amount of site traffic generated (ADT, AM and PM Peaks).
- ✓ Determine where the site traffic will be coming from and going to.
- ✓ Distribute your primary trips into the “approved” driveway connections.
- ✓ Determine any geometric improvements needed or, any driveway alterations.

Example #1

Existing Traffic Volumes



General Office Building (710)

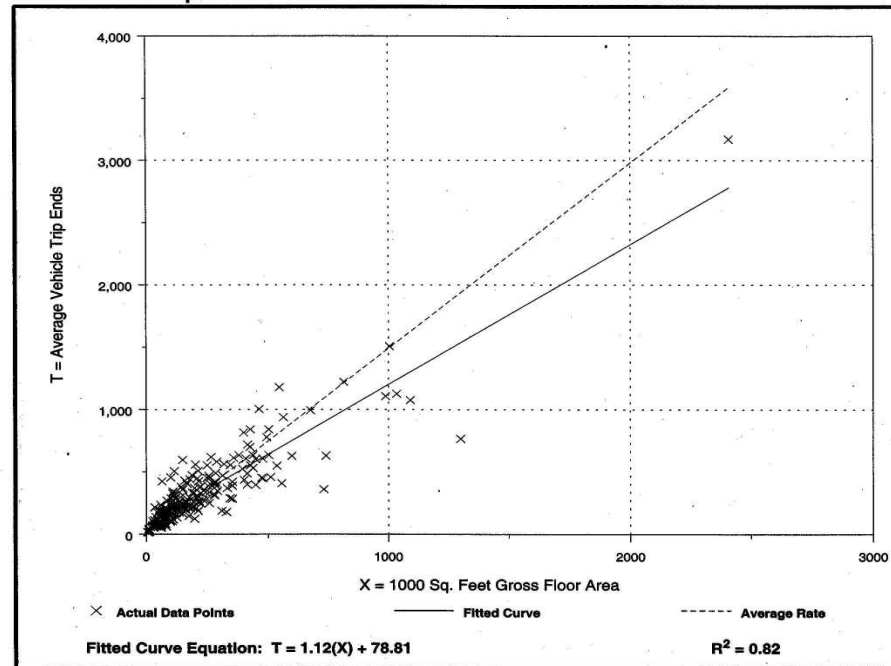
Average Vehicle Trip Ends vs: 1000 Sq. Feet Gross Floor Area
On a: Weekday,
P.M. Peak Hour

Number of Studies: 235
 Average 1000 Sq. Feet GFA: 216
 Directional Distribution: 17% entering, 83% exiting

Trip Generation per 1000 Sq. Feet Gross Floor Area

Average Rate	Range of Rates	Standard Deviation
1.49	0.49 - 6.39	1.37

Data Plot and Equation



General Office Building (710)

X = 200,000 SQ Feet GFA

PM Peak: Trip Generation Manual (7th Edition)

Equation: $T = 1.12(X) + 78.81$ $R^2 = 0.82$

$$T = 1.12 * (200) + 78.81$$

T = 302.81 Trips in the PM Peak

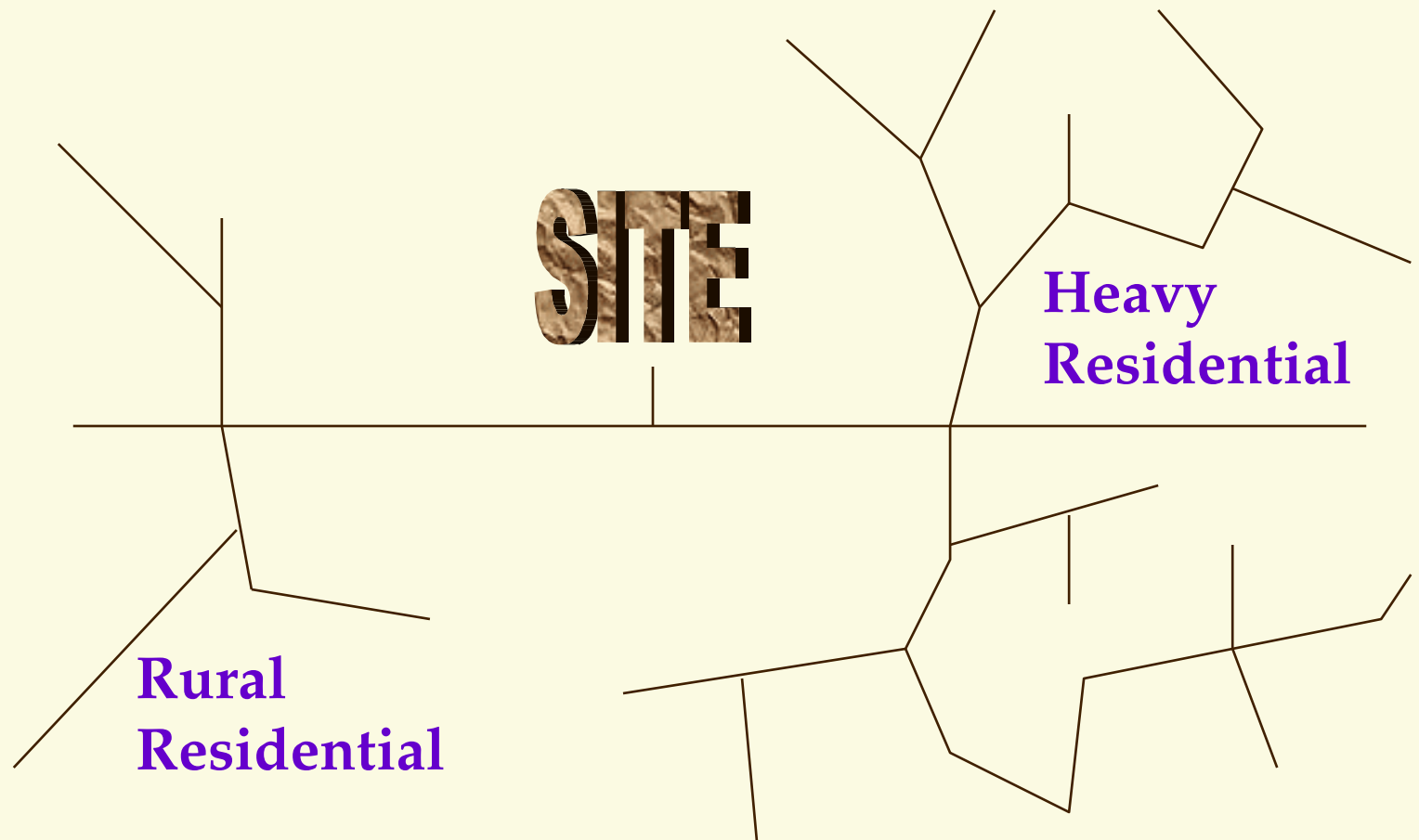
Enter: $(17\%) * (303) = 52$ vehicles

Exit: $(83\%) * (303) = 252$ vehicles

or use:

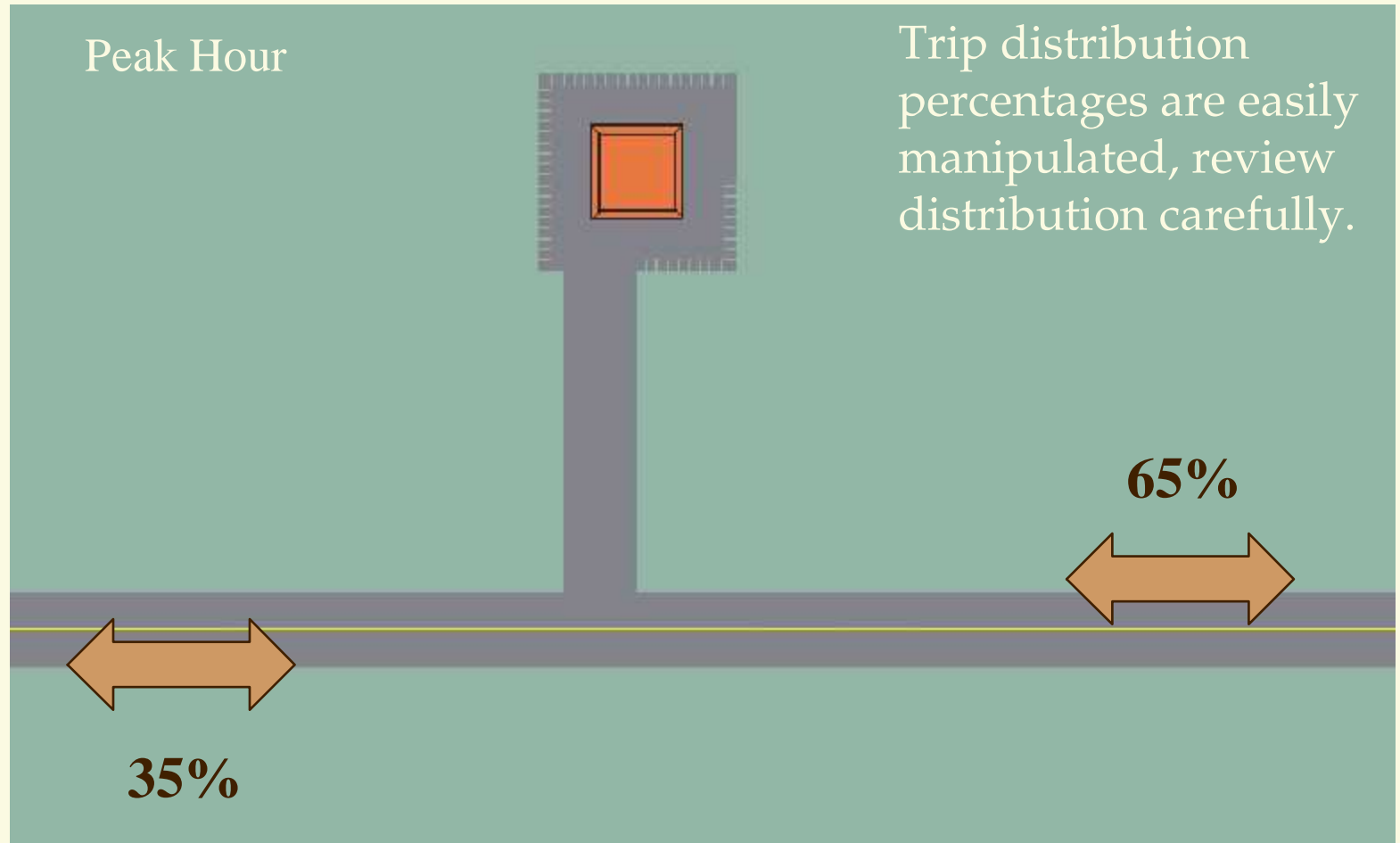
Average Rate: $1.49 * (200) = 298$ Trips

Area Map



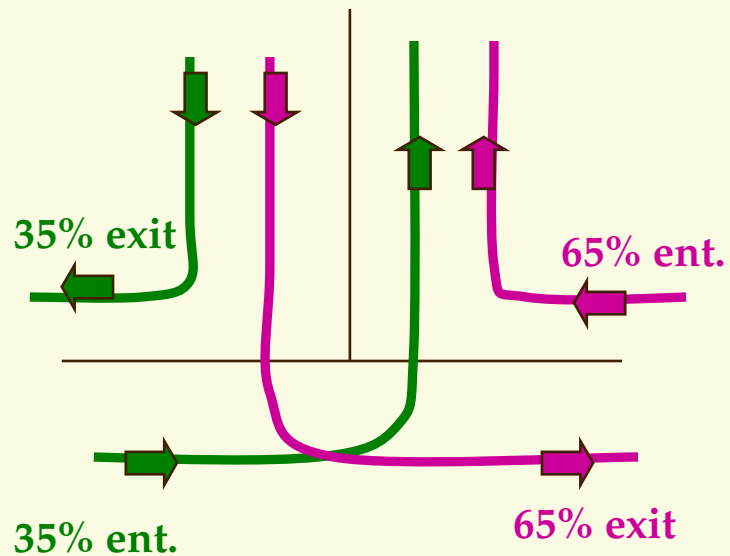
Example #1

Site Trip Assignment



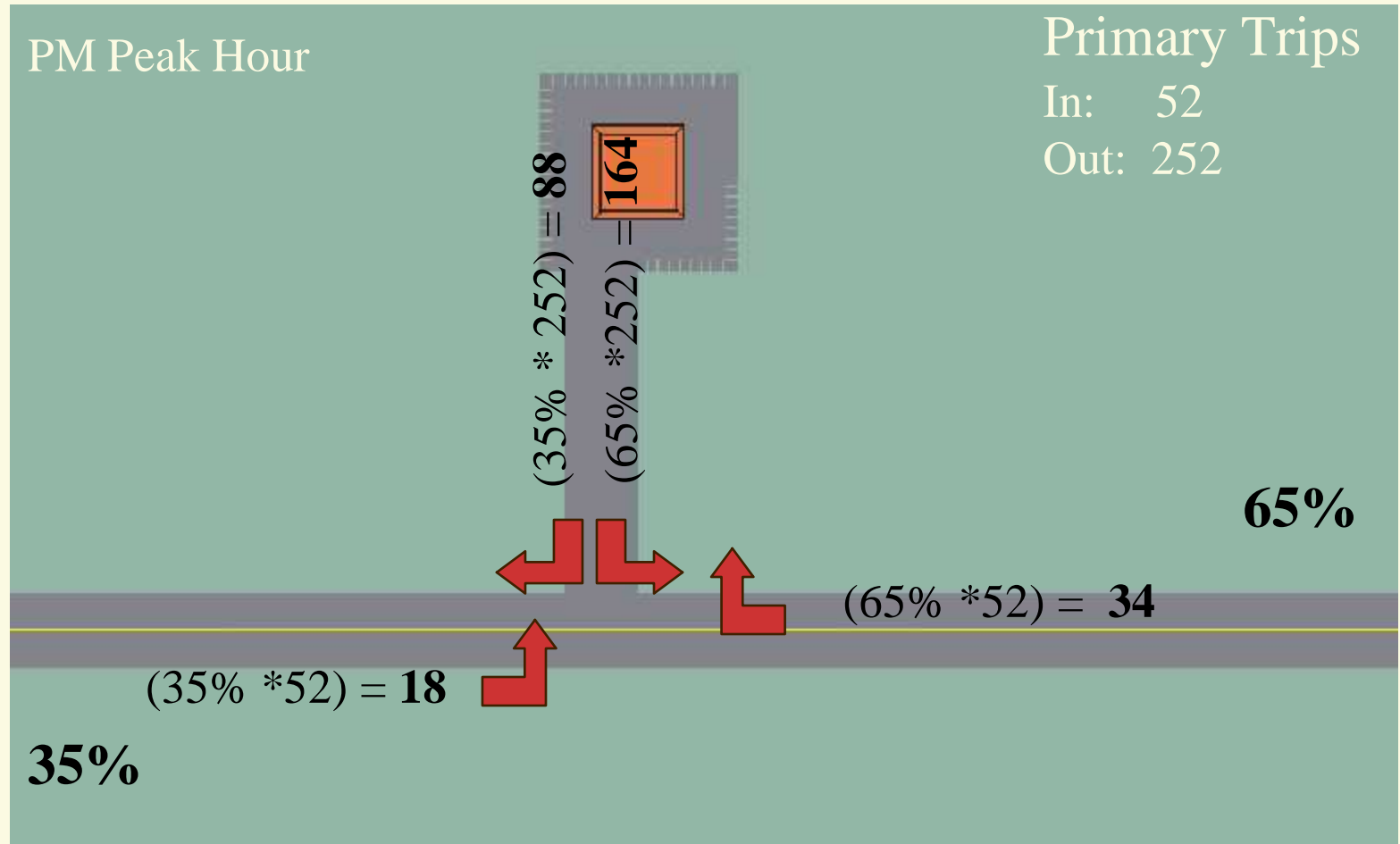
Primary Trips

Primary Traffic



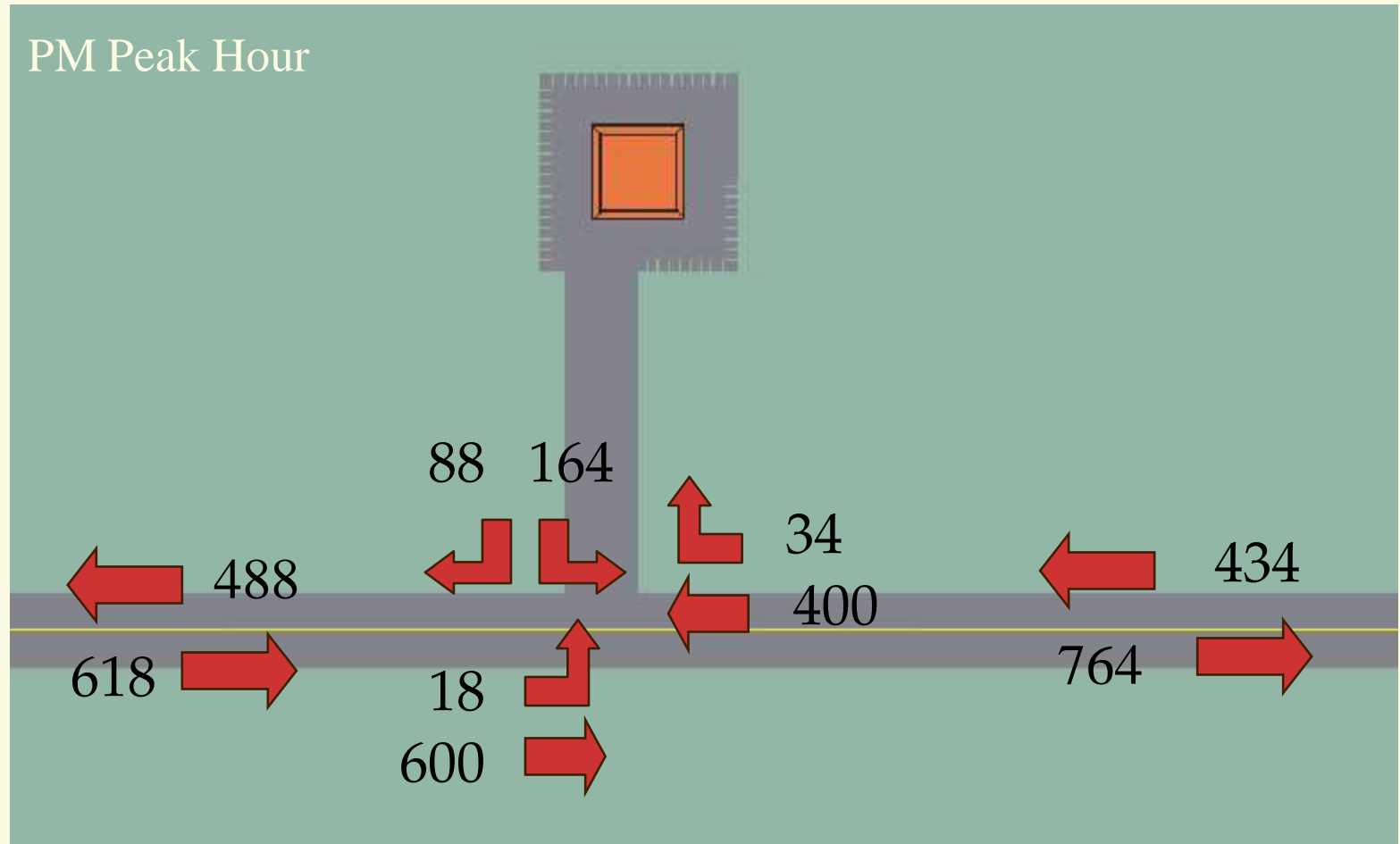
Example #1 General Office Building

Primary Site Trips



Example #1

Combined Volumes (existing plus site traffic)



Engineering Decisions:

- ✓ Number of Driveway Connections Appropriate?
- ✓ Configuration of the Requested Driveway? Control-of-Access Limits?
- ✓ Correlation to Intersections/Existing Nearby Driveway Connections? Interconnectivity?
- ✓ Horizontal and Vertical Sight Distance Met?
- ✓ Traffic Operation of New Intersection (delay, gaps, queuing, etc.)
- ✓ Are Auxiliary Lanes Needed? Storage Lengths?
- ✓ Consideration for signalization?
- ✓ Conforms to Median Crossover Guidelines?

Note: Refer to Policy on Street and Driveway Access to North Carolina Highways

Practice Problem

- ✓ Simple problem, one land use.
- ✓ Apply procedures for previous example.

Pass-by Trips

- ✓ Pass-by trip - Intermediate stops made 'on the way' from an origin to a primary destination.
- ✓ Pass-by trips apply to retail and service land uses only. (LUC 800's and 900's)
- ✓ Both primary trips and diverted trips are not considered pass-by trips.
- ✓ Pass-by trip distribution is based on trip distribution for the base volumes.
- ✓ CAUTION! - Pass-by must be taken from appropriate land use when Trip Generation is calculated.

Pass-by Charts and Equation

- ✓ Pass-by charts display pass-by percentages from sample location to provide a standard to base your estimations.

- Many percentages may be high - use discretion.

- ✓ Equation to calculate pass-by percentage*

Pass-by Regression Equation Example:

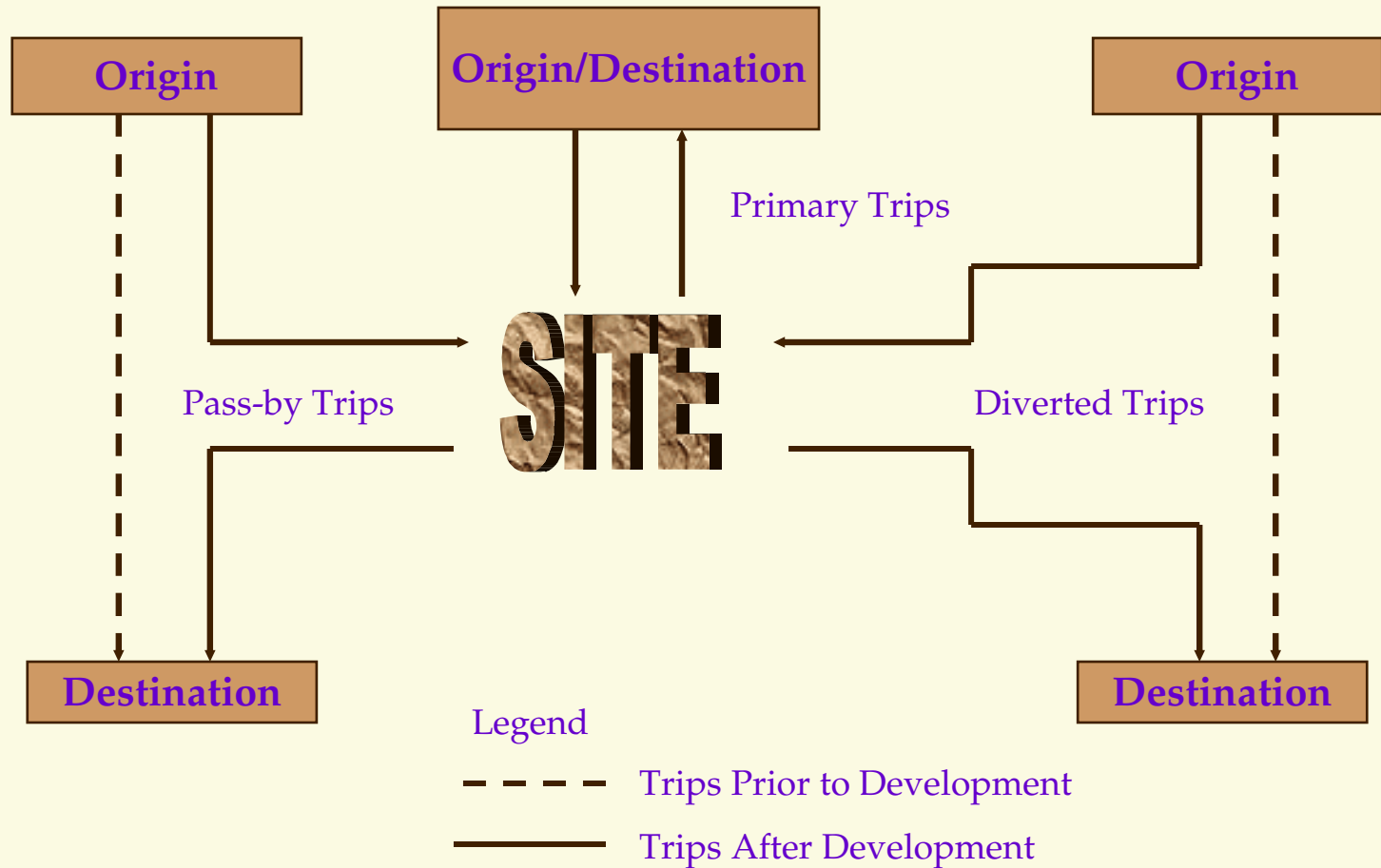
$$\text{Ln(PB)} = -0.291 \text{ Ln}(x) + 5.001 \quad \text{where } x = 1,000 \text{ SF of GLA}$$

* Equation is for a Shopping Center (LUC 820) only

Diverted Trip

- ✓ Trips using a segment of the transportation system that they previously were not using to access the proposed development site.
- ✓ Count as new trips where they travel on segments required to reach the site where they previously did not travel.
- ✓ Diverted Trips are very rare and utilizing diverted trips should be analyzed carefully.

Types of Trips



Trip Generation Data Sheet

Example #2 (Multi-Entrances on a Single Frontage)

Land Use: Shopping Center (250,000 SF)

Land Use Code: 820 Variable(s): 1,000 SF GLA

- ✓ 45 mph posted speed
- ✓ 4-lane divided facility
- ✓ (12 foot lanes, 16 foot median)
- ✓ ADT = 23,000
- ✓ Two full movement driveways requested with 800 feet of separation and 900 feet of frontage

Median Crossover Guidelines (July 1998)

General Guidelines:

- ✗ A median crossover shall not be allowed unless an adequate length left turn deceleration lane and taper can be provided in both directions of travel.
- ✗ Median crossovers shall not be located where sight distance (both vertical and horizontal) cannot meet minimum NCDOT criteria.
- ✗ Median crossovers shall not be placed in areas where the grade of the crossover will exceed 5%.
- ✗ A median crossover should not be provided where the median width is less than 16 feet.

Urban Divided Highways Without Full Control of Access (operating speeds between 45 and 55 mph)

- ✓ In urban situations, there is usually more demand for median crossovers. Due to the density of the development and lower traffic speeds, it is acceptable to provide a closer spacing of median crossovers in urban areas.
- ✓ The spacing of crossovers will be largely dependent upon the need for adequate storage for left turning vehicles/U-turning vehicles at intersections. **A crossover shall not be placed where it interferes with the storage requirement for existing intersections.**
- ✓ Crossovers shall not be spaced any closer than 1000 feet apart on urban divided highways with operating speeds between 45 and 55 mph.

Example #2 Shopping Center

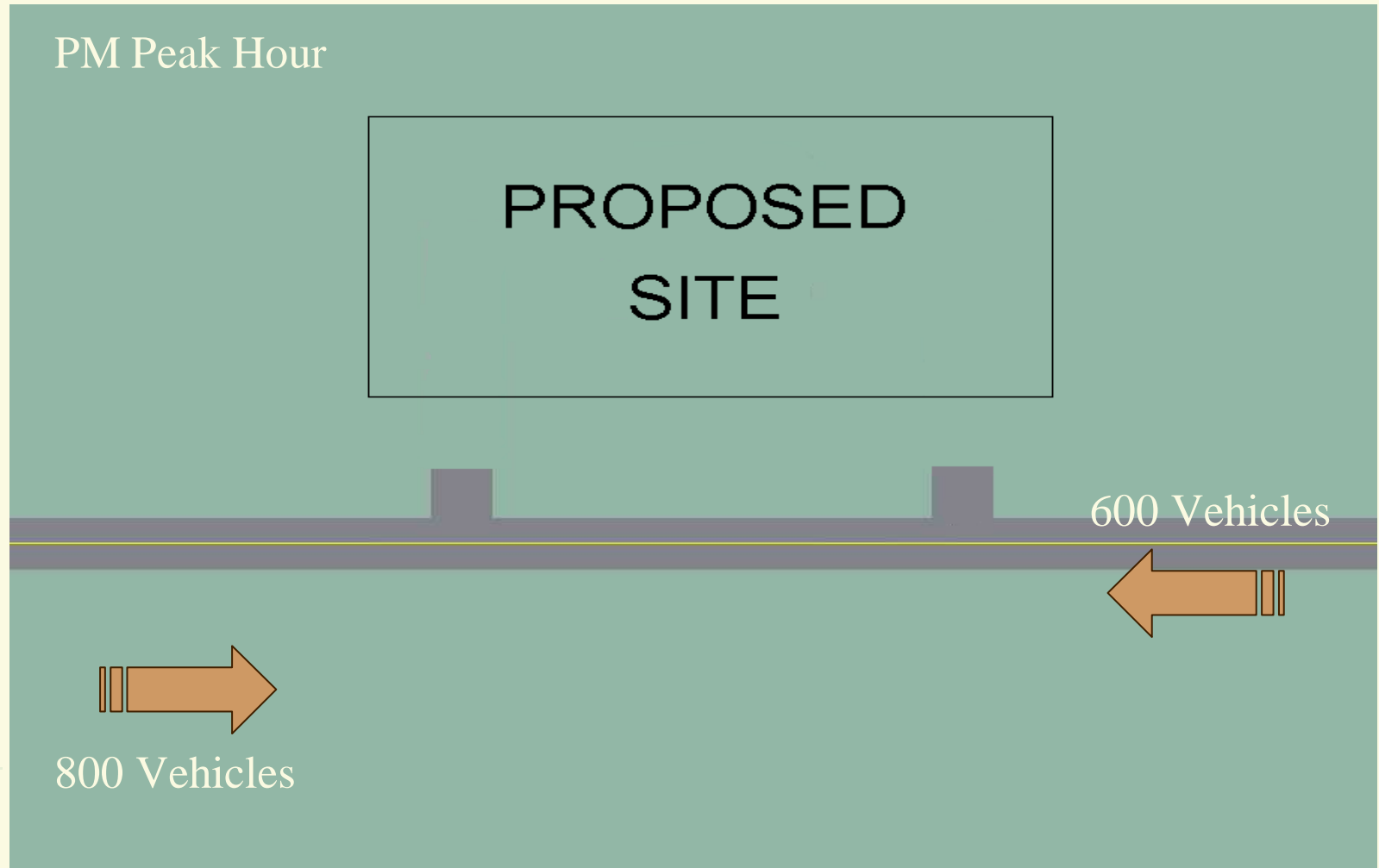
Existing Traffic Volumes

PM Peak Hour

PROPOSED
SITE

600 Vehicles

800 Vehicles



Shopping Center (820)

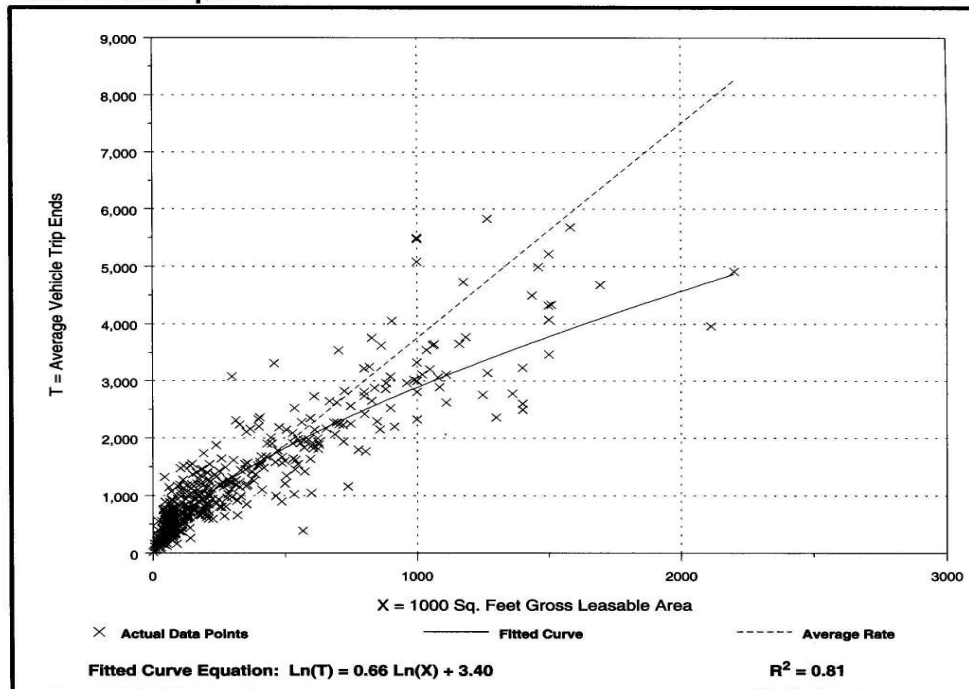
Average Vehicle Trip Ends vs: 1000 Sq. Feet Gross Leasable Area
On a: Weekday,
Peak Hour of Adjacent Street Traffic,
One Hour Between 4 and 6 p.m.

Number of Studies: 407
 Average 1000 Sq. Feet GLA: 379
 Directional Distribution: 48% entering, 52% exiting

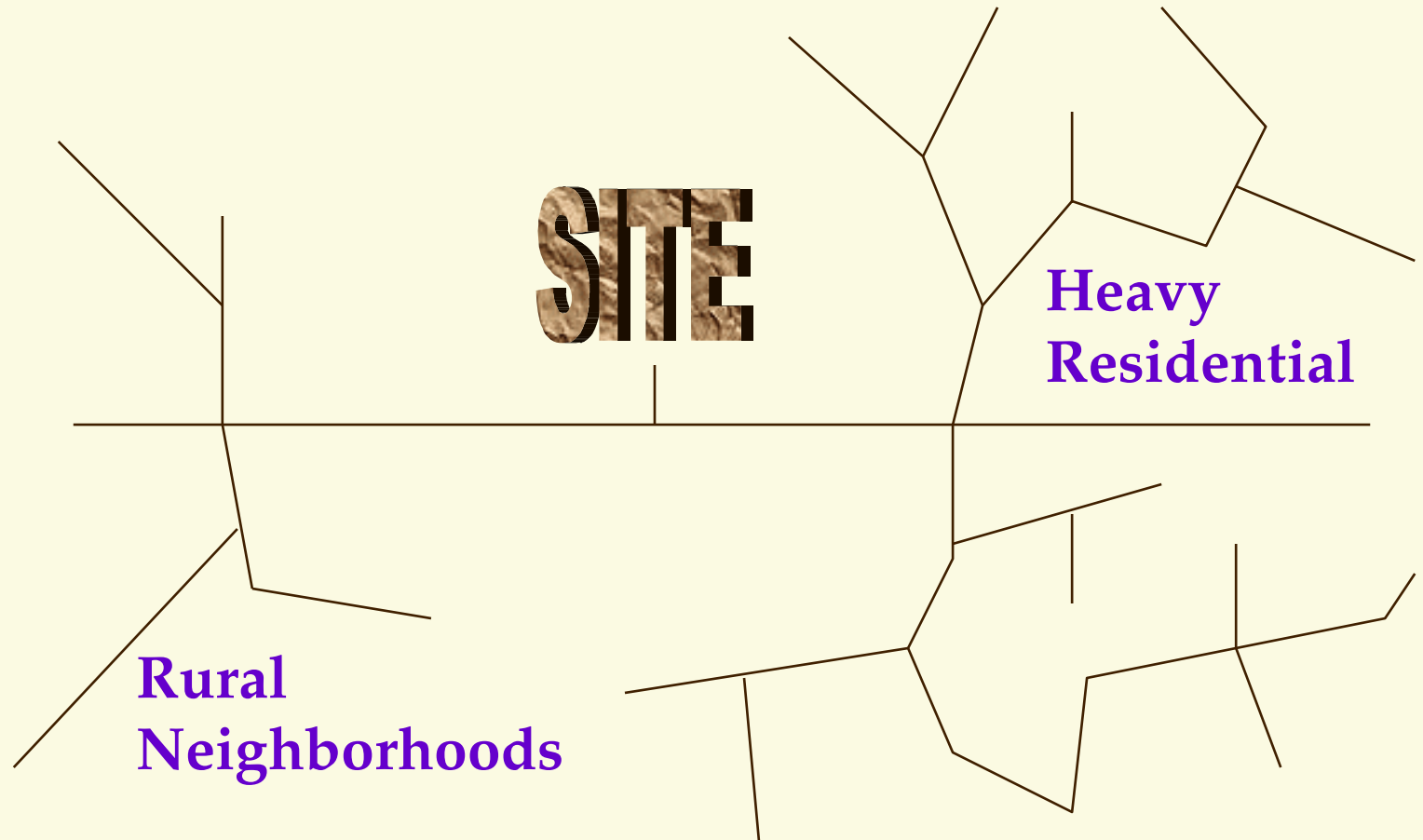
Trip Generation per 1000 Sq. Feet Gross Leasable Area

Average Rate	Range of Rates	Standard Deviation
3.75	0.68 - 29.27	2.75

Data Plot and Equation



Area Map



Shopping Center (820)

250,000 SF GLA

PM Peak: Trip Generation Manual (6th Edition)

Equation: $\ln(T) = 0.660 \ln(X) + 3.40$ $R^2 = 0.81$

$$\ln(T) = 0.660 \ln(250) + 3.40$$

$$\ln(T) = 3.64 + 3.40$$

$$\ln(T) = 7.044$$

$T = 1,146$ Trips in the PM Peak

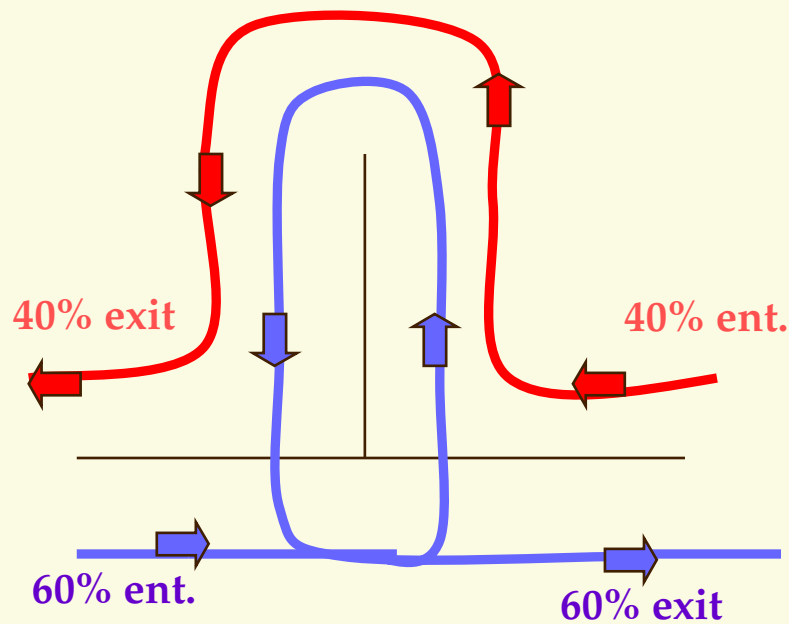
Enter: 48% (1,146) = 550 vehicles

Exit: 52% (1,146) = 596 vehicles

or use:

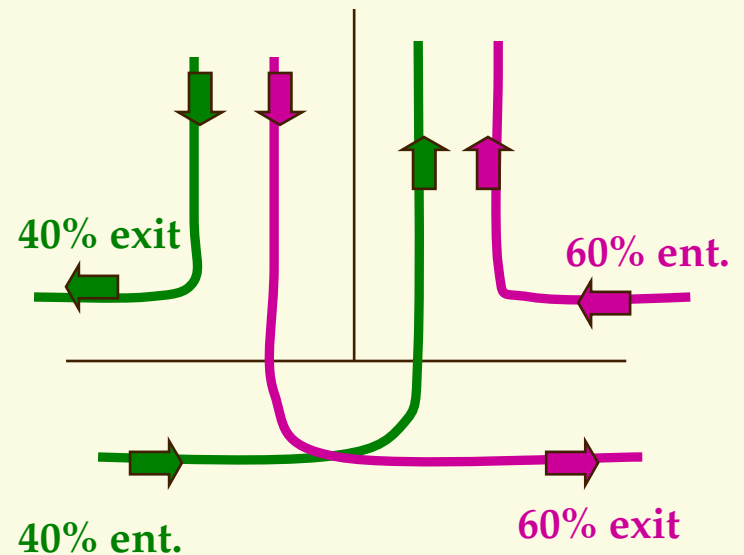
Average Rate: $3.75 (250) = 938$ Trips in the PM Peak

Pass-By and Primary Trips



Pass-By Traffic

Primary Traffic



Pass-By and Primary Trip Calculations

Pass-by Tables:

Estimate that roughly 30% of new trips will be pass-by trips based on shopping centers of a similar size (250,000 sq. ft.)

Total PM Peak Trips = **1,146** (found earlier)

Pass-By Trips = 30% of 1,146 = **344 trips**

in: 50% of 344 = **172**

out: 50% of 344 = **172**

Primary Trips = 70% of 1,146 = **802 trips**

in: 48% of 802 = **385**

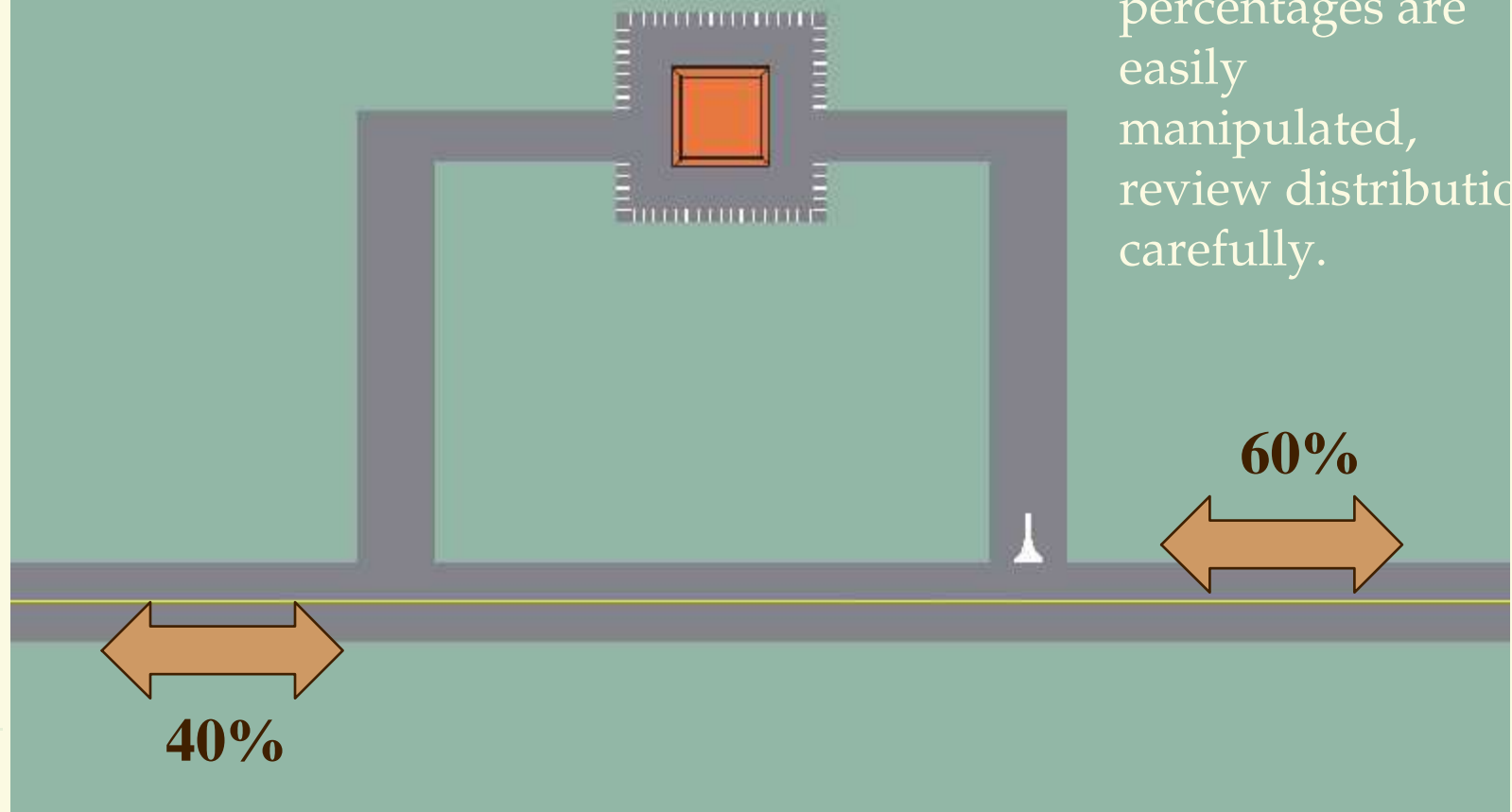
out: 52% of 802 = **417**

Example #2 Shopping Center

Primary Site Trip Assignment

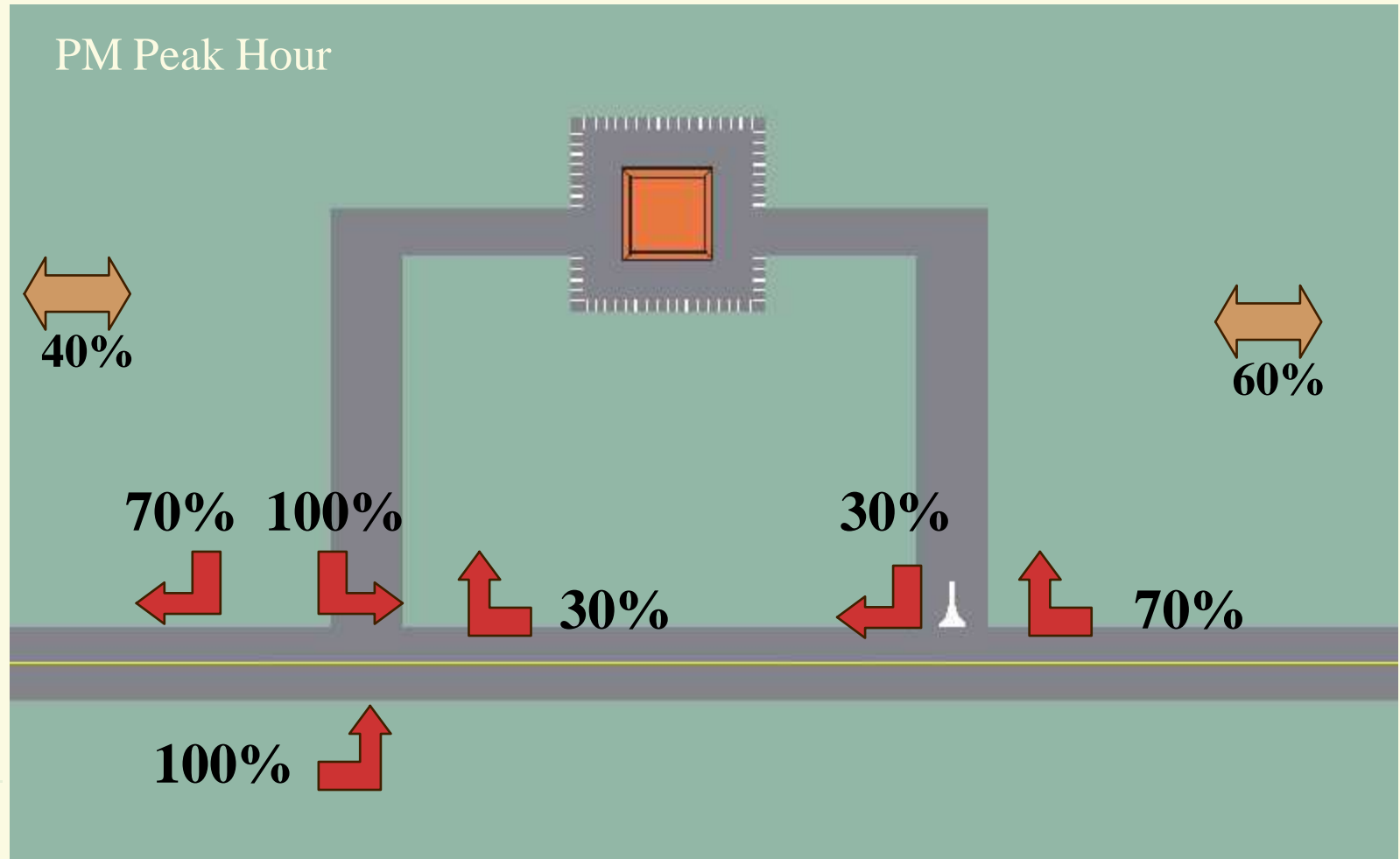
Peak Hour

Trip distribution percentages are easily manipulated, review distribution carefully.



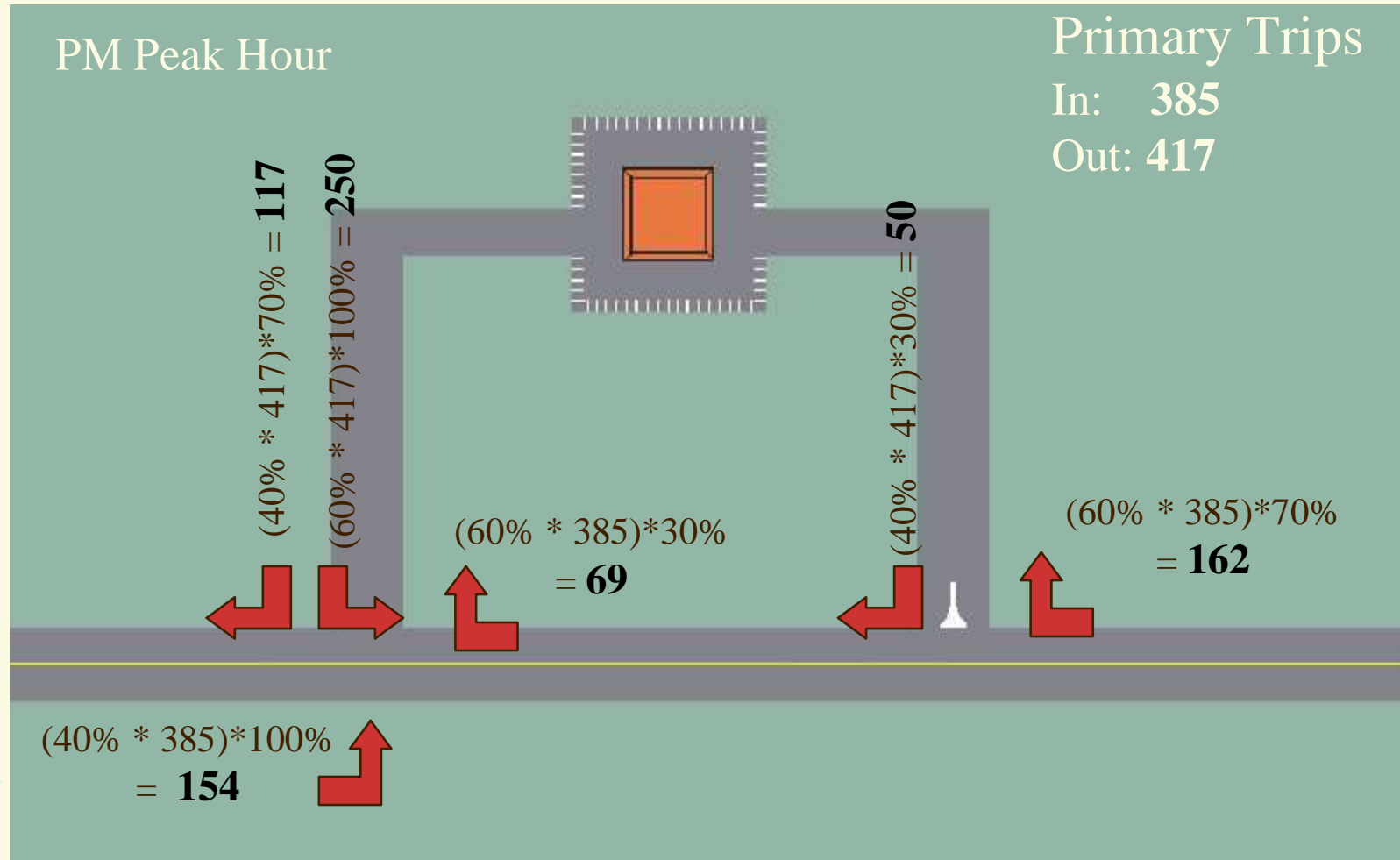
Example #2 Shopping Center

Primary Site Trip Assignment



Example #2 Shopping Center

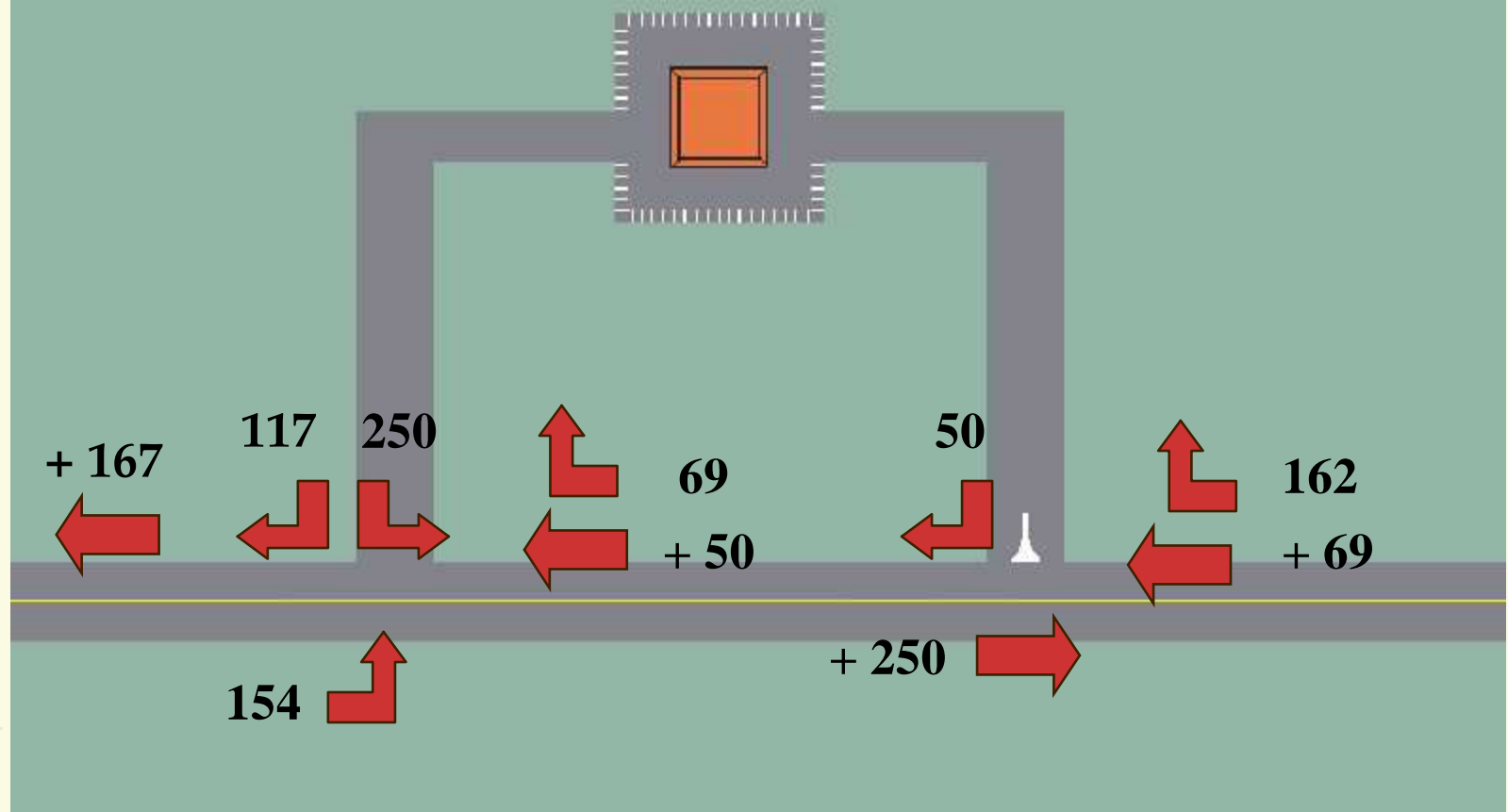
Primary Site Trip Breakdown



Example #2 Shopping Center

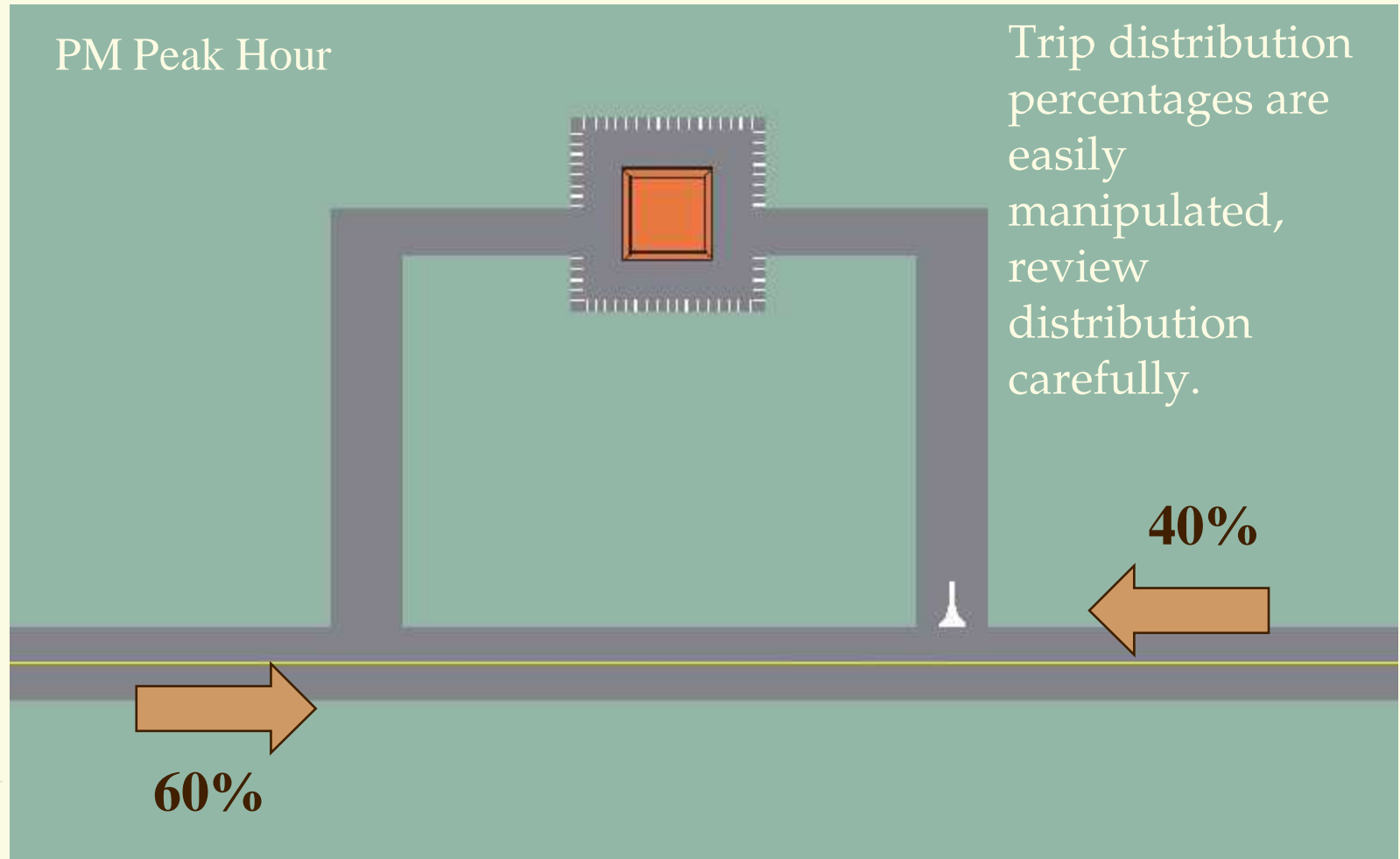
Primary Volumes Only

PM Peak Hour



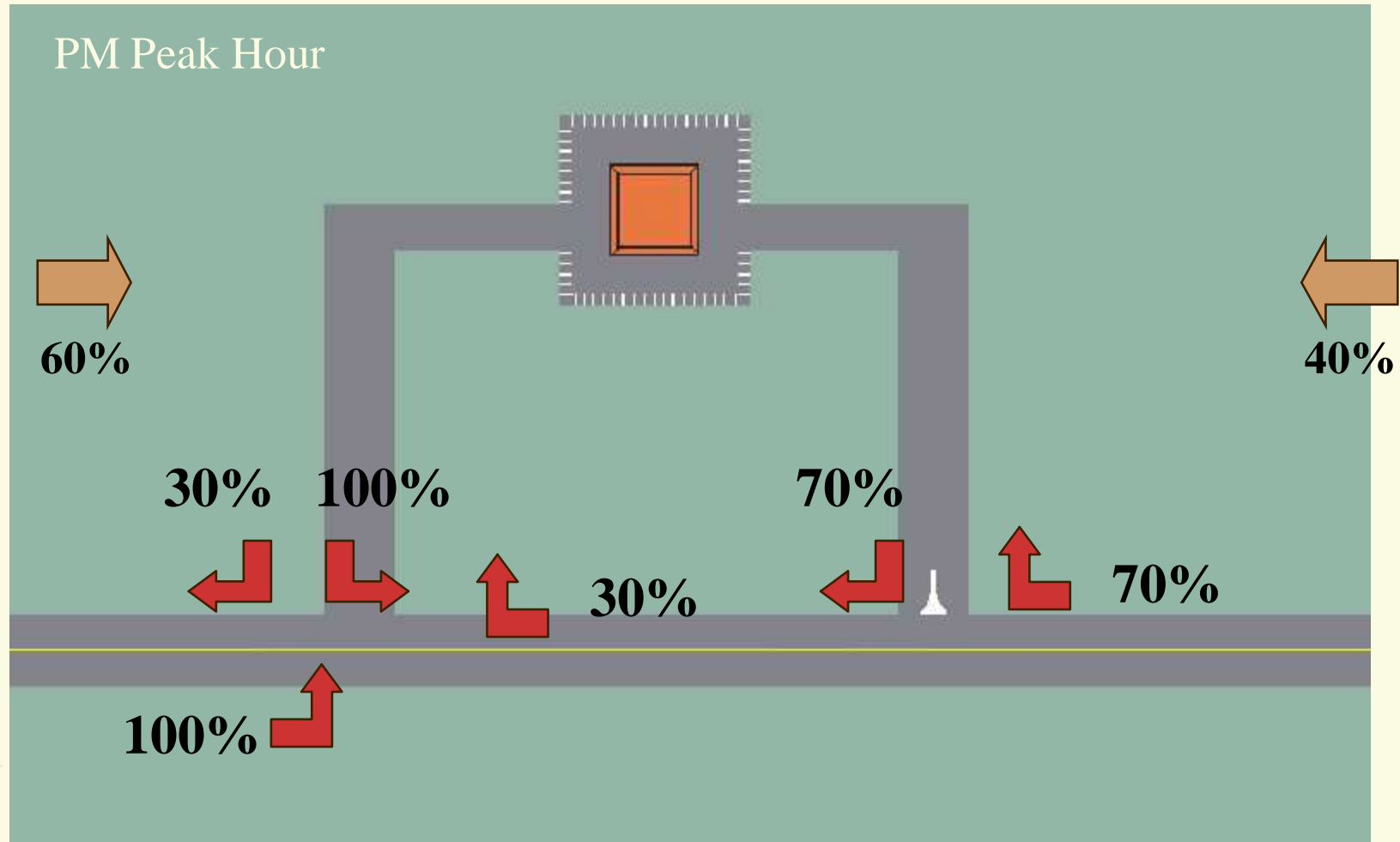
Example #2 Shopping Center

Pass-by Site Trip Assignment



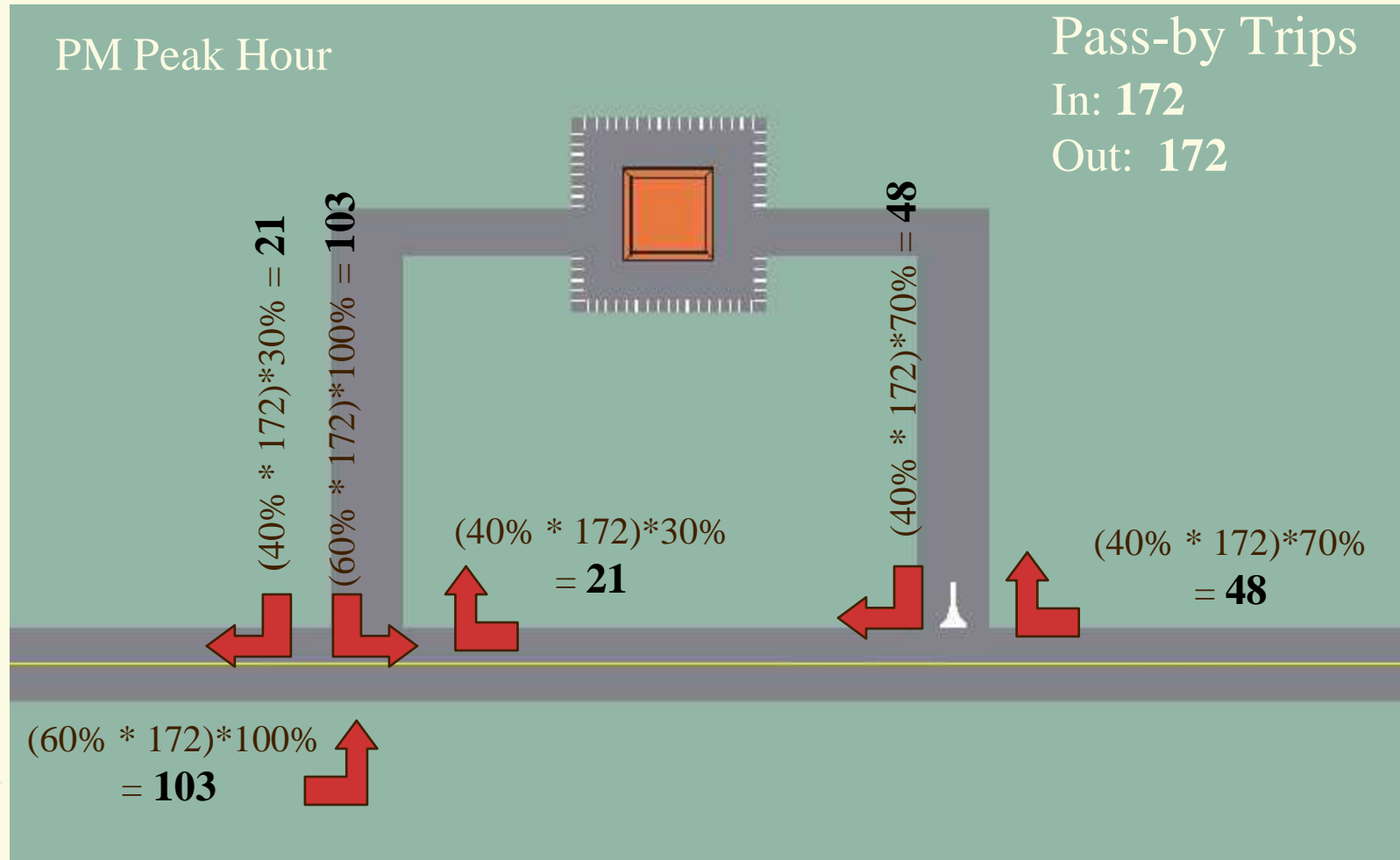
Example #2 Shopping Center

Pass-by Site Trip Assignment



Example #2 Shopping Center

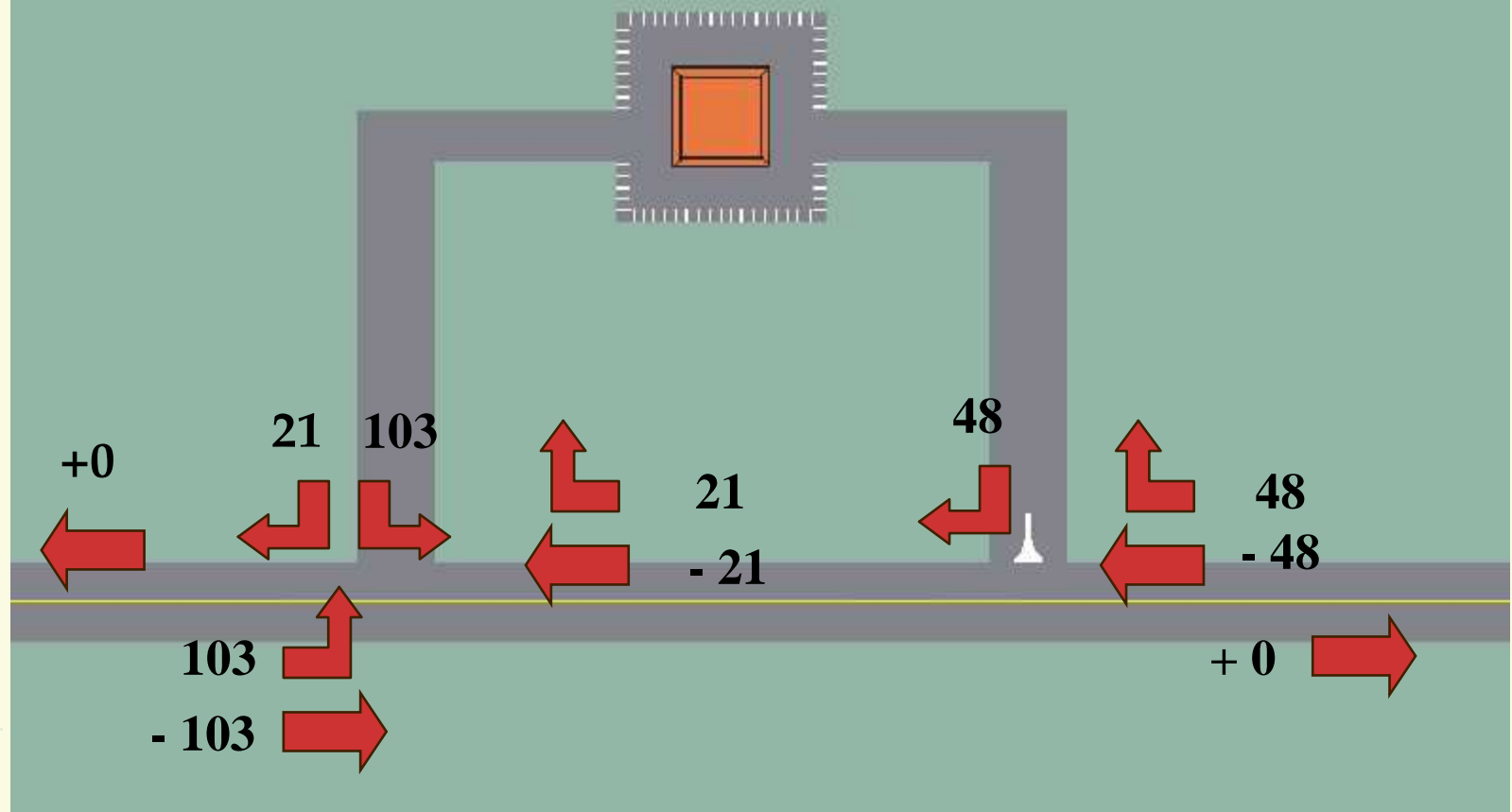
Pass-by Site Trip Breakdown



Example #2 Shopping Center

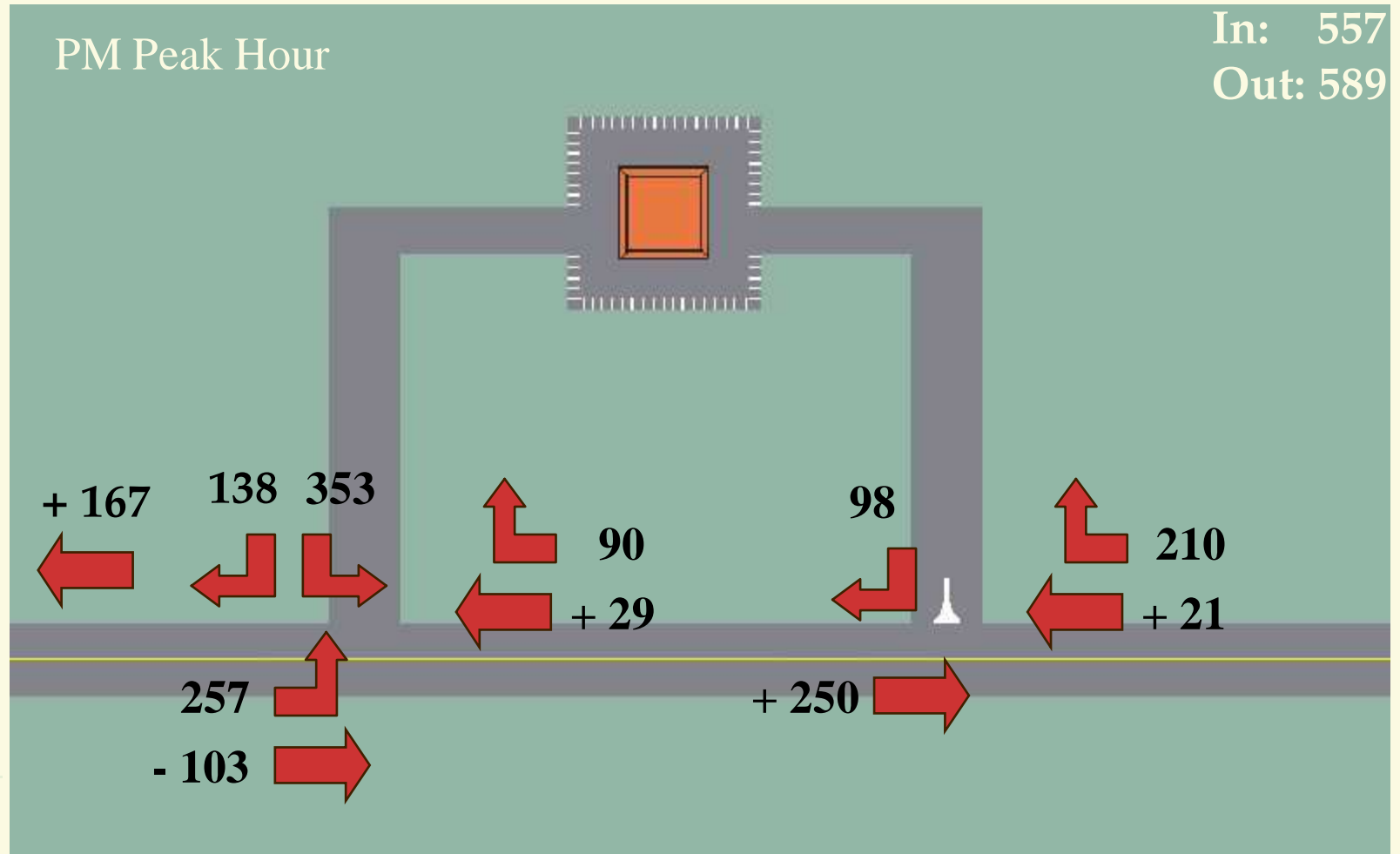
Pass-by Volumes Only

PM Peak Hour



Example #2 Shopping Center

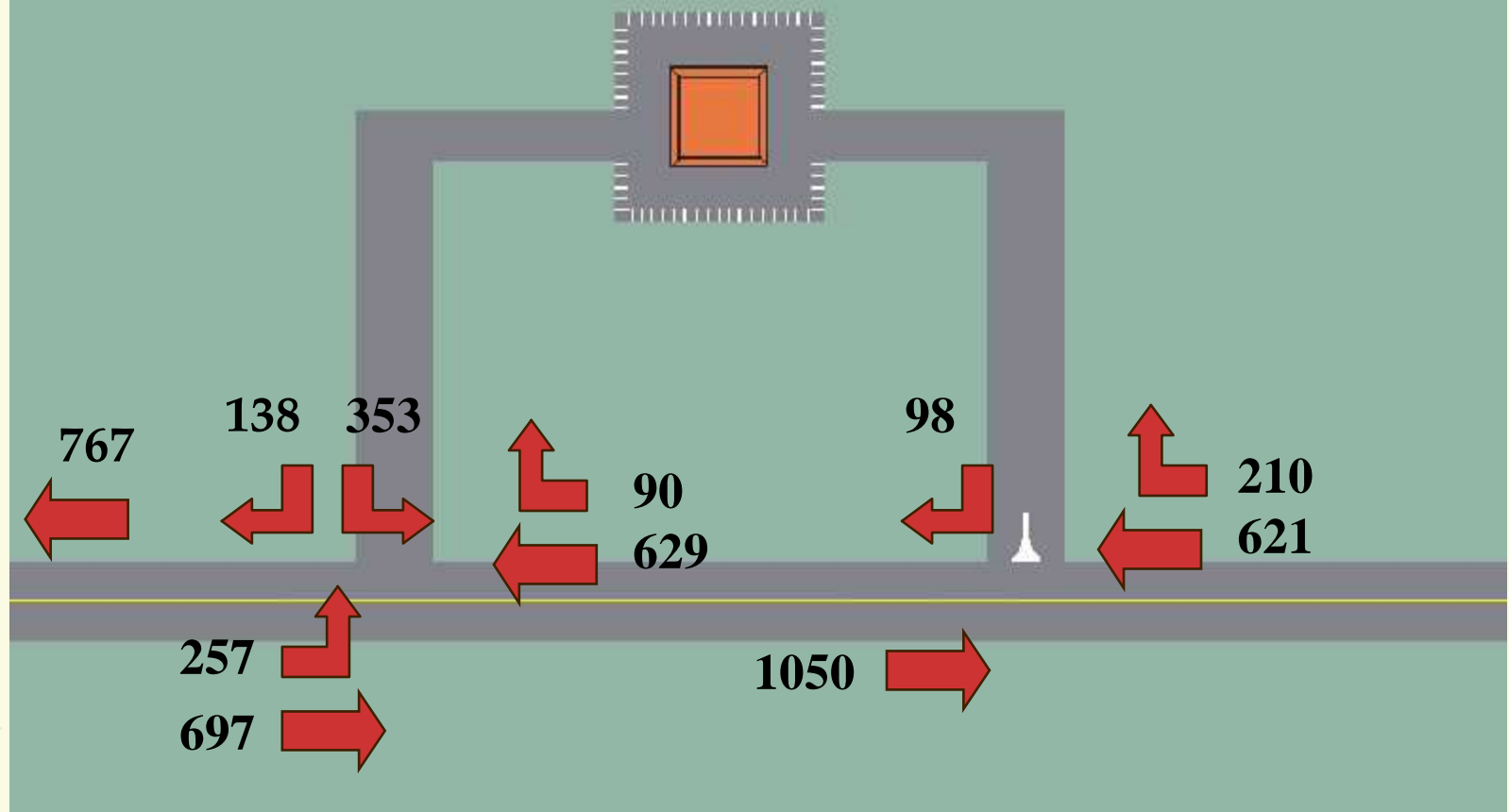
Pass-by and Primary Driveway Volumes



Example #2 Shopping Center

Combined Volumes (existing plus site traffic)

PM Peak Hour



Engineering Decisions:

- ✓ Number of Driveway Connections Appropriate?
- ✓ Configuration of the Requested Driveway? Control-of-Access Limits?
- ✓ Correlation to Intersections/Existing Nearby Driveway Connections? Interconnectivity?
- ✓ Horizontal and Vertical Sight Distance Met?
- ✓ Traffic Operation of New Intersection (delay, gaps, queuing, etc.)
- ✓ Are Auxiliary Lanes Needed? Storage Lengths?
- ✓ Consideration for signalization?
- ✓ Conforms to Median Crossover Guidelines?

Note: Refer to Policy on Street and Driveway Access to North Carolina Highways

Practice Problem

- ✓ Applying pass-by reduction.
- ✓ Two land uses, two driveways.
- ✓ Apply procedures from previous problems.

Internal Capture

- ✓ A percentage reduction in trips to account for trips made internal to the site.
- ✓ Only seen in multi-use developments
- ✓ Must be applied before pass-by reduction
- ✓ Driveway Manual thresholds apply to trip generation calculations prior to reductions for internal capture and pass-by.

Computing Internal Capture

- ✓ Estimate baseline Trip Generation for site
- ✓ Estimate internal capture percentages between each pair of land uses (Table 7.1 and 7.2 of the Trip Generation Handbook)
- ✓ Estimate “Unconstrained Demand” volume by direction
- ✓ Estimate “Balanced Demand” volume by direction
- ✓ Estimate total internal trips made to/from land uses
- ✓ Estimate total external trips for each land use
- ✓ Calculate internal capture percentage

Internal Capture Example

- ✓ Development consist of:
 - 600 Apartments
 - 300 Single Family Homes
 - 4,000 sq. ft. High Turnover (Sit-Down) Restaurant
 - 500,000 sq. ft. General Office
 - 250, 000 sq. ft. Shopping Center
- ✓ All land uses represented in ITE Trip Generation Manual

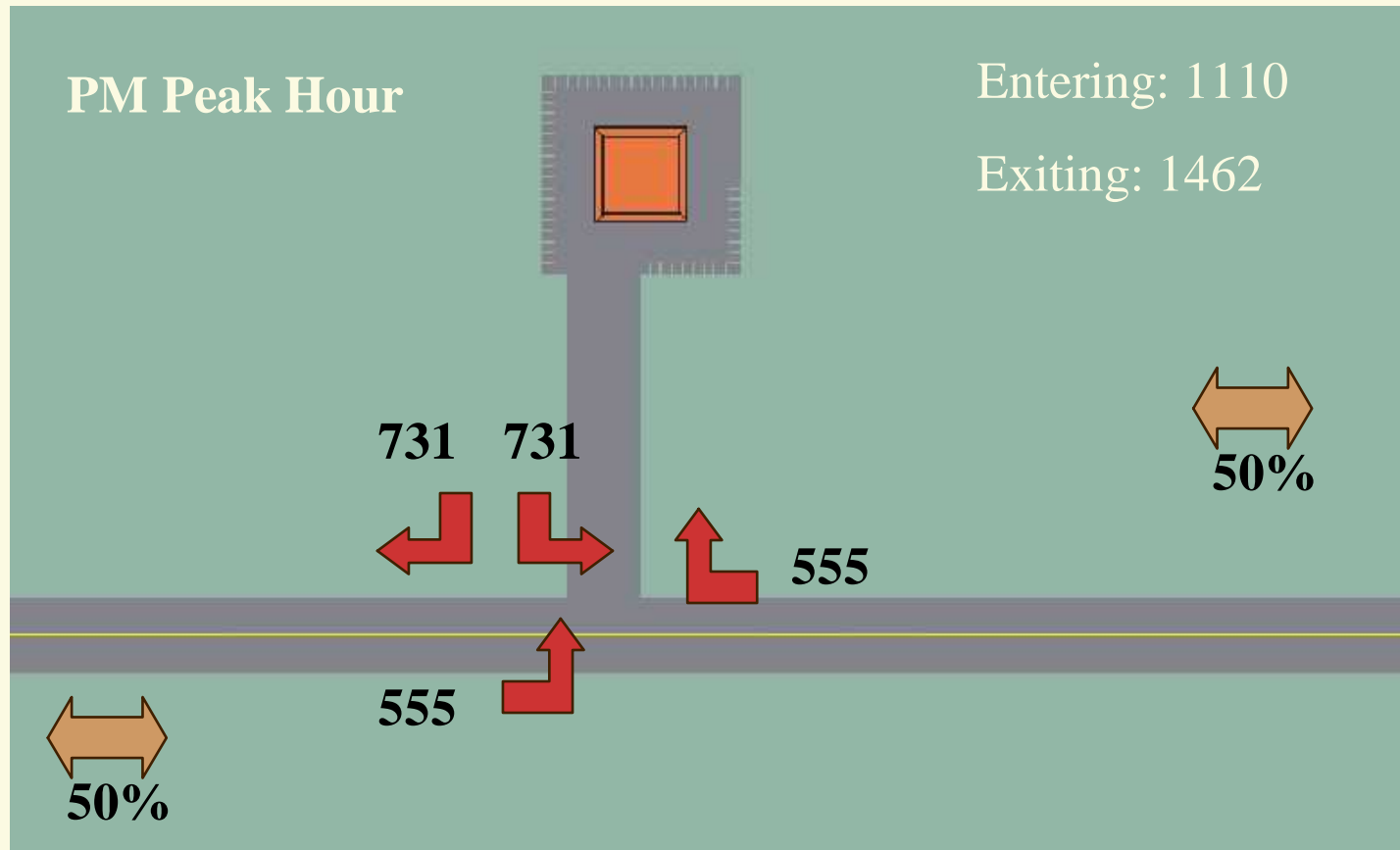
Internal Capture Example (cont.)

- ✓ 1. Is this a Multi-Use site? Yes
- ✓ 2. Time Period? PM Peak
- ✓ 3. Trip Generation

Land Use	Size	24 Hour Two-Way Volume	AM Pk Hour		PM Pk Hour	
			Enter	Exit	Enter	Exit
Apartments	600 Dwelling Units	3756	60	238	226	122
Single Family Detached Housing	300 Dwelling Units	2857	55	165	182	107
High Turnover (Sit-Down) Restaurant	4 Th.Gr.Sq.Ft.	509	24	22	27	17
General Office Building	500 Th.Gr.Sq.Ft.	5505	680	95	125	620
Shopping Center	250 T.G.L.A.	12320	165	106	550	596
Total		24947	984	626	1110	1462

Internal Capture Example (cont.)

Primary Site Trips



Internal Capture Example (cont.)

✓ 4. Internal Capture Rates between Land Uses - Origins

Table 7.1 Unconstrained Internal Capture Rates for Trip Origins within a Multi-Use Development

		WEEKDAY		
		MIDDAY PEAK HOUR	P.M. PEAK HOUR OF ADJACENT STREET TRAFFIC	DAILY
from OFFICE	to Office	2%	1%	2%
	to Retail	20%	23%	22%
	to Residential	0%	2%	2%
from RETAIL	to Office	3%	3%	3%
	to Retail	29%	20%	30%
	to Residential	7%	12%	11%
from RESIDENTIAL	to Office	N/A	N/A	N/A
	to Retail	34%	53%	38%
	to Residential	N/A	N/A	N/A

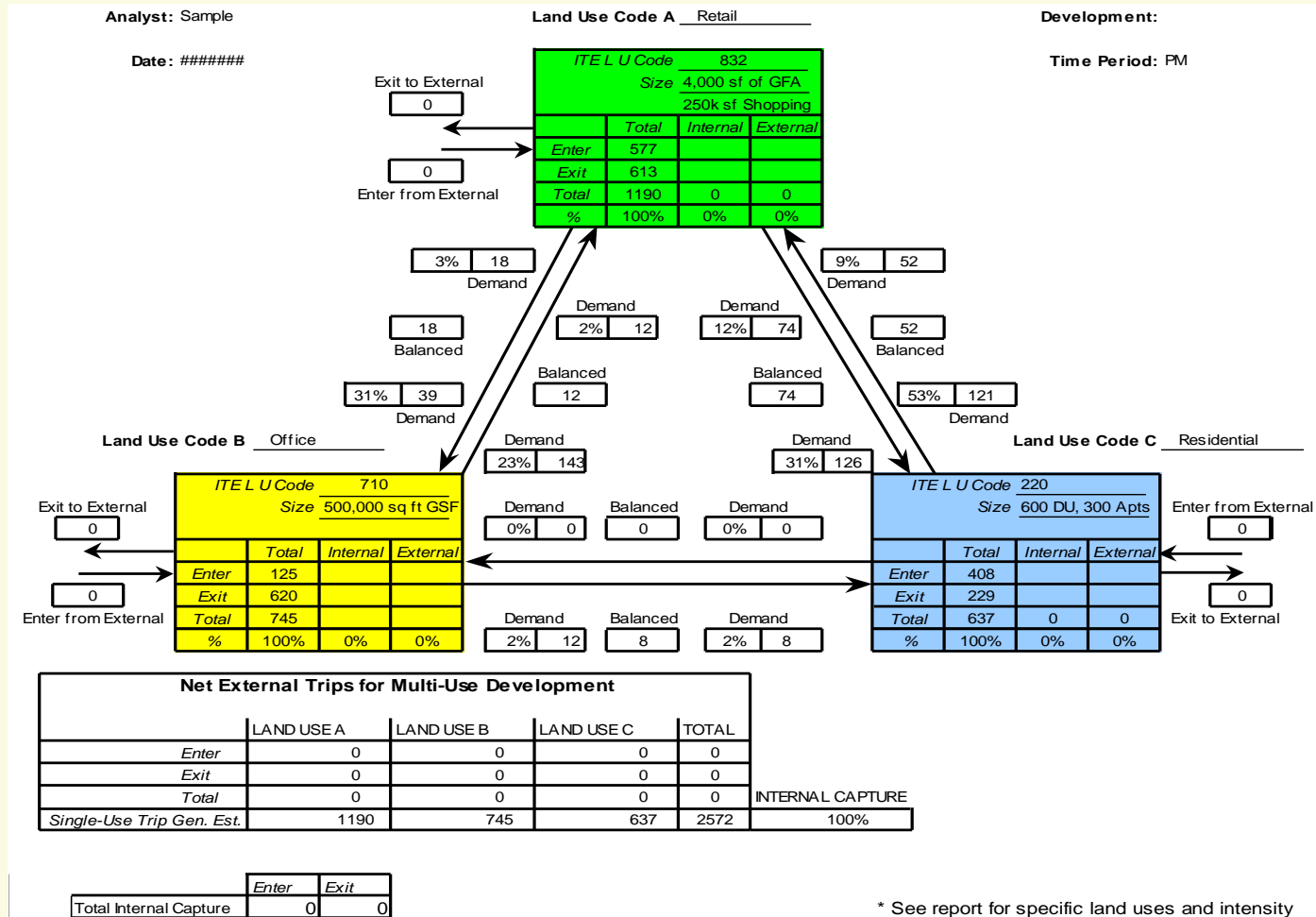
Internal Capture Example (cont.)

✓ 4. Internal Capture Rates between Land Uses - Destinations

Table 7.2 Unconstrained Internal Capture Rates for Trip Destinations Within a Multi-Use Development

		WEEKDAY		
		MIDDAY PEAK HOUR	P.M. PEAK HOUR OF ADJACENT STREET TRAFFIC	DAILY
to OFFICE	from Office	6%	6%	2%
	from Retail	38%	31%	15%
	from Residential	0%	0%	N/A
to RETAIL	from Office	4%	2%	4%
	from Retail	31%	20%	28%
	from Residential	5%	9%	9%
to RESIDENTIAL	from Office	0%	2%	3%
	from Retail	37%	31%	33%
	from Residential	N/A	N/A	N/A

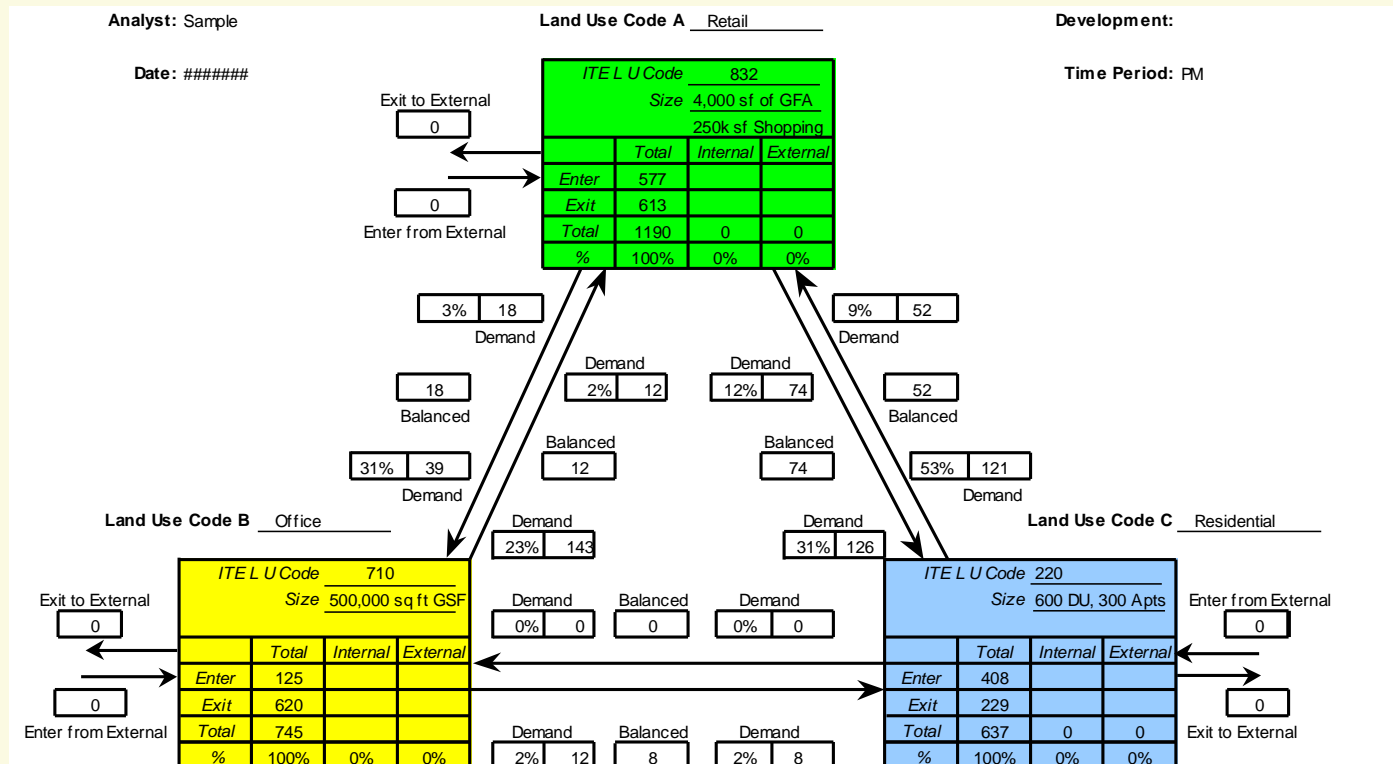
Internal Capture Example (cont.)



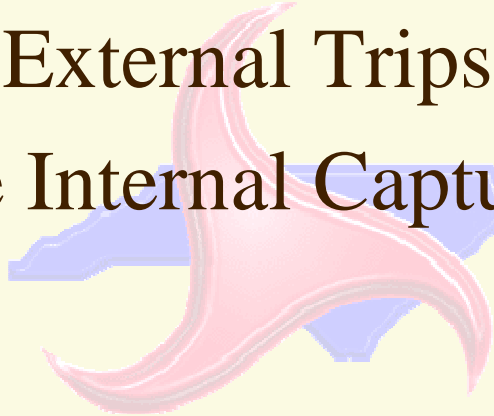
* See report for specific land uses and intensity

Internal Capture Example (cont.)

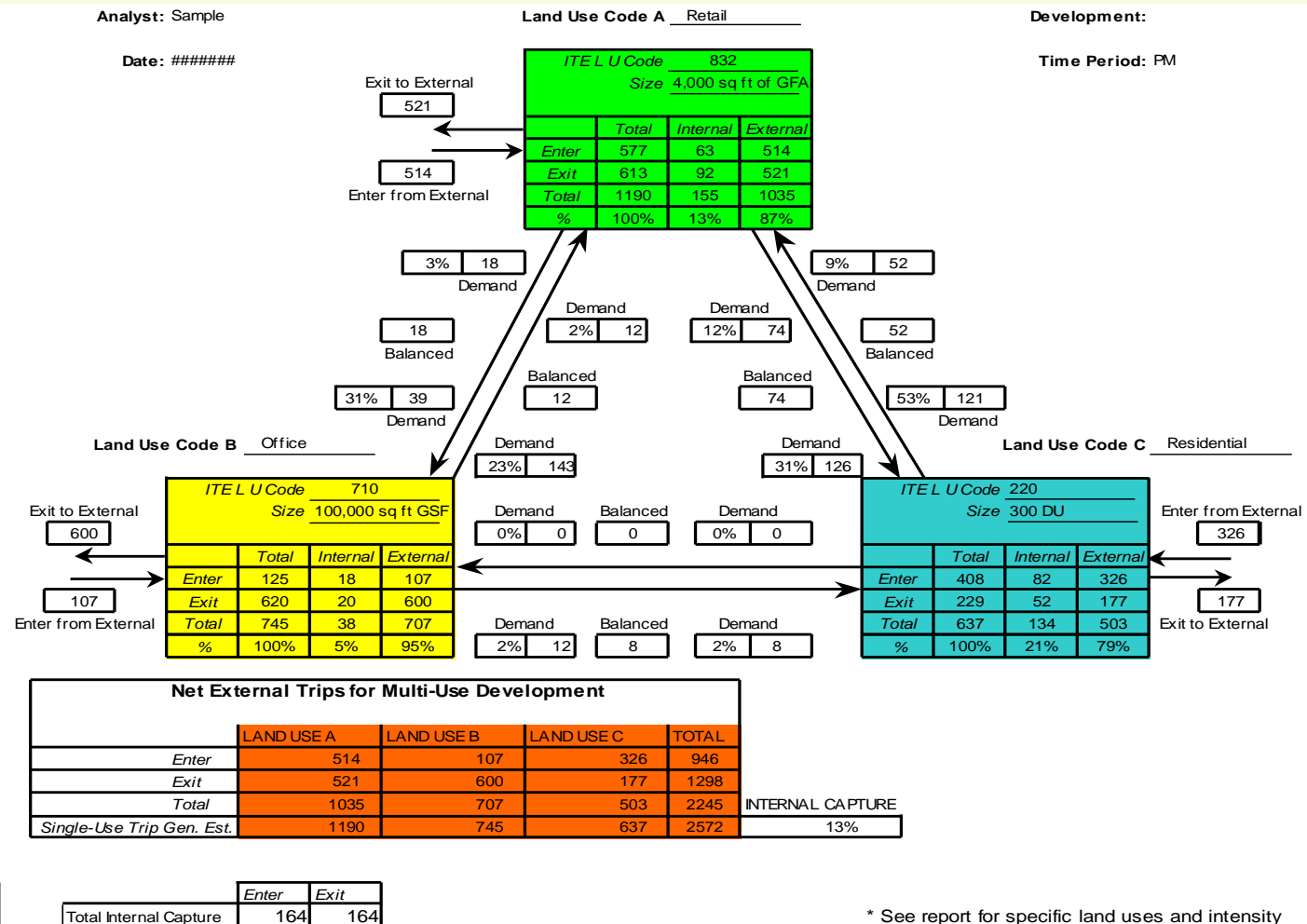
- ✓ 5. Unconstrained Demand
- ✓ 6. Balanced Demand



Internal Capture Example (cont.)

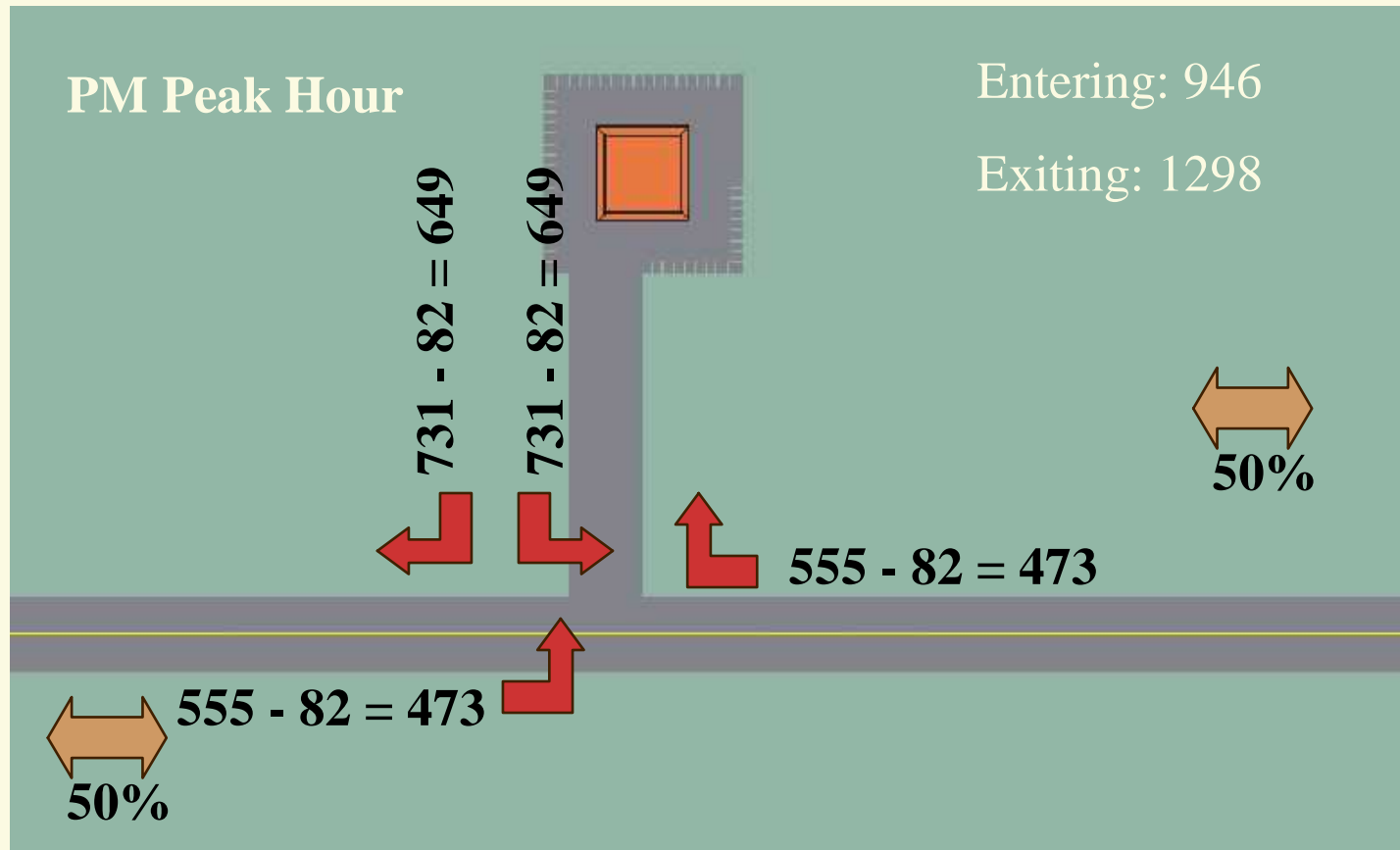
- ✓ 7. Estimate to/from Internal Trips
 - ✓ 8. Estimate External Trips
 - ✓ 9. Calculate Internal Capture Rate
- 

Internal Capture Example (cont.)

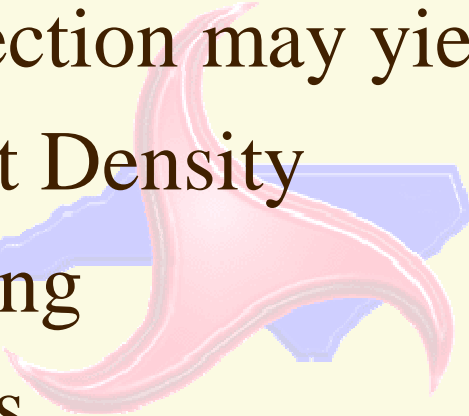


Internal Capture Example (cont.)

Reduced Primary Site Trips



Precautions for Internal Capture

- ✓ Tables illustrates small sample size - local data collection may yield better results.
 - ✓ Development Density
 - ✓ Shared Parking
 - ✓ Pass-by Trips
- 

Precautions

Note: If any of the following points are discovered during an analysis of the Trip Generation performed for a development, proper documentation shall be provided to explain the reason for it's use.

- ✓ Incorrect method (rate vs. equation)
- ✓ Using an incorrect independent variable
- ✓ Analyzing adjacent street peak hour instead of peak hour generator, vise versa
- ✓ Analyzing an incorrect land use (read descriptions)
- ✓ Inaccurate pass-by calculation (applying one pass-by percentage for all land uses)

Precautions (cont.)

- ✓ Be aware of unorthodox reductions in traffic
- ✓ High pass-by & internal capture percentages
- ✓ Using Internal Capture rates for retail land uses
- ✓ Not providing both AM and PM counts
- ✓ Combining like land uses with one total independent variable
- ✓ Using an older manual
- ✓ Using another trip generation source other than ITE (i.e. generation rates from a county or municipality)

Final Practice Problem

- ✓ Review trip generation outputs for errors.
- ✓ Apply principles discussed throughout the training.

Contacts and Information

- ✓ Obviously, these examples are very simple. Nearly all developments will be more difficult and complex.
- ✓ Should you need assistance in the future, please contact myself or Teresa Becher at (919) 250-4151 or by e-mail.

tbecher@dot.state.nc.us

dhspencer@dot.state.nc.us

Thank you!